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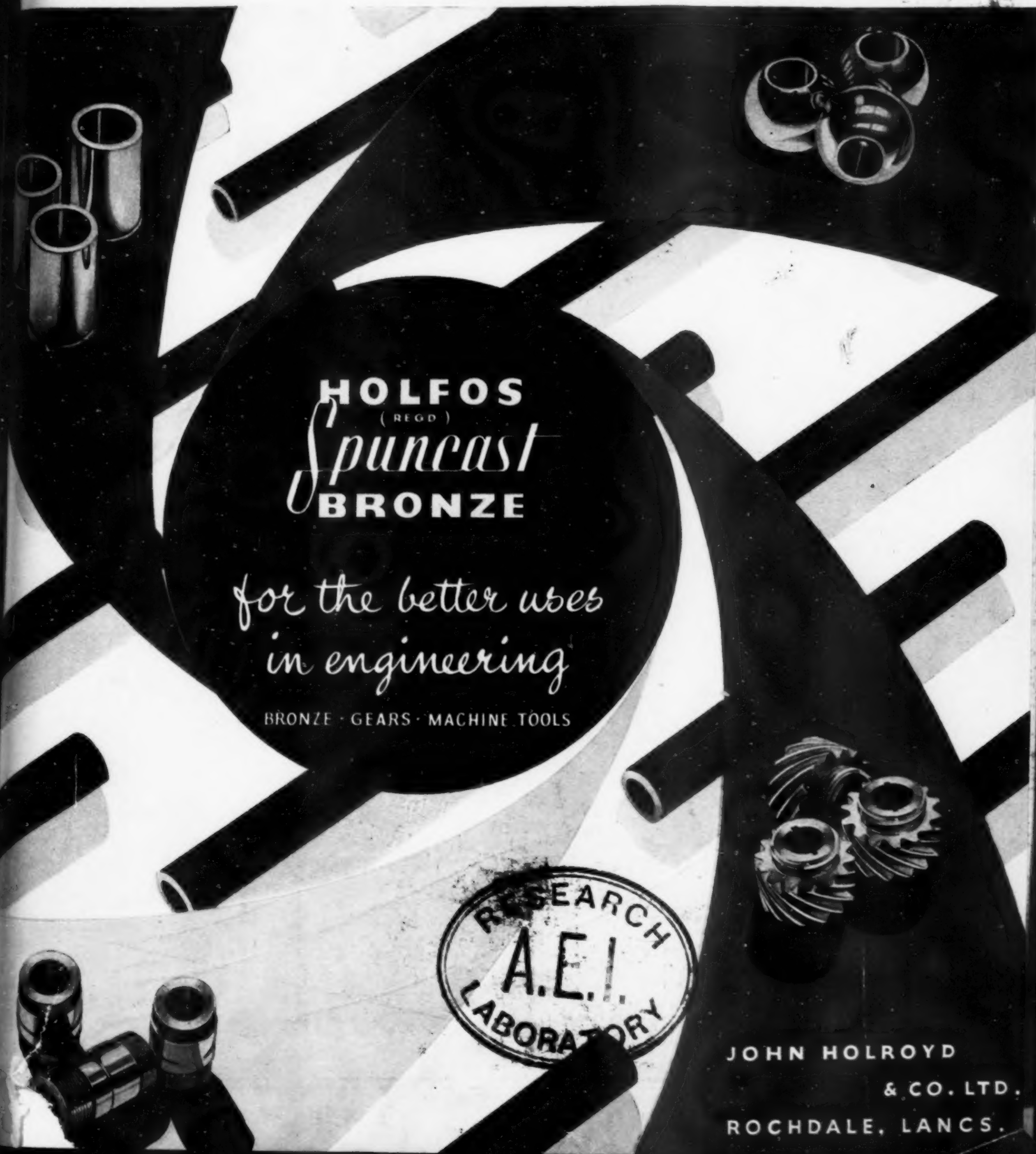

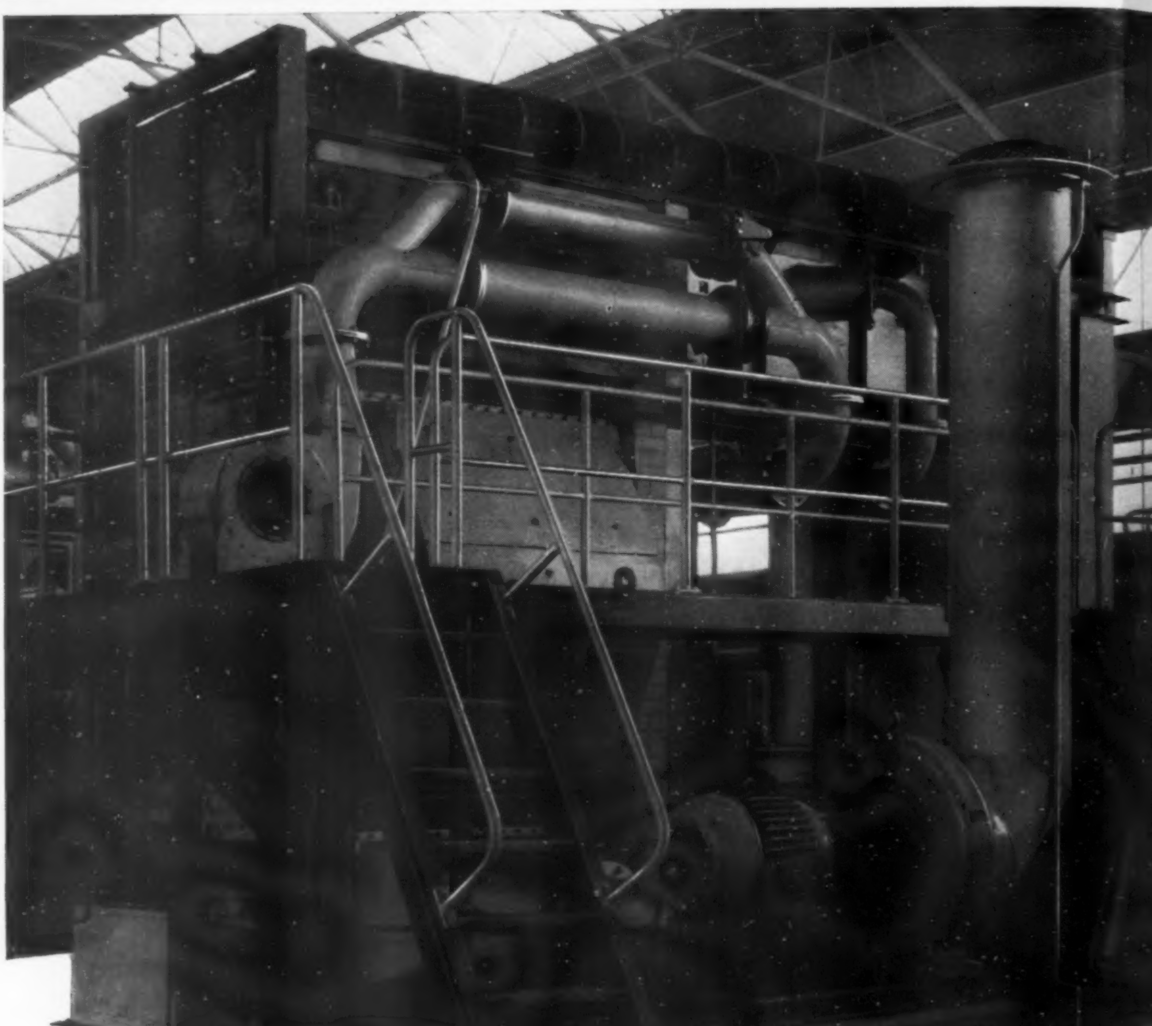
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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JUNE, 1953 Vol. XLVII. No. 284

Long Live the Queen!

CORONATIONS, like Christmas, are occasions of rejoicing and celebration, but, like Christmas also, they have a much deeper significance. In the past, the accent, for most people, has been on the pageantry and jollifications, for only a comparatively small number can be accommodated in Westminster Abbey for the Coronation ceremony. The advent of television, however, has wrought a change of far-reaching importance, in that, on June 2nd, millions of people in this country, and on the Continent of Europe, were able to see the Archbishop of Canterbury as he placed the Crown of St. Edward on the head of our young sovereign, Queen Elizabeth II, and, so it seemed, to take part in the service. For the successful televising of this moving ceremony, the highest praise is due to the B.B.C., and it now seems incredible that the idea of televising the Abbey ceremony was at one time frowned upon.

There was a time when the right to wear the Crown gave rise to dispute, and when certain parts of the ceremony possessed a deeper and more practical significance than they do to-day. The line of succession is now well established, and if ever the Queen entertained any doubts about the loyalty and affection of her peoples, those doubts must have been swiftly dispelled by the reception given to her and to H.R.H. The Duke of Edinburgh on Coronation Day and on the many public appearances they have made since.

Much has been written in recent weeks on the subject of our monarchy, and attention has been drawn to the many paradoxes associated with it and with the Commonwealth. The fact remains, however, that it has survived the viscissitudes of fortune over several hundred years—a period which included a spell without a sovereign—and that it is now more firmly established than ever in the hearts of the people of this land. This is, no doubt, due to the way in which it has adapted itself to the changing conditions in the world around it, but perhaps the greatest single factor in this evolution has been the character of those who have occupied the throne in the last four or five decades. In particular, the inspiring example of self-sacrifice and devotion to duty shown by King George VI, especially during the difficult and dangerous years from 1939 to 1945, did much to endear him to his people. Throughout his reign he received constant support and encouragement from his wife, and at a time like the present, Queen Elizabeth the Queen Mother must recollect with pride the manifestations of love and affection which poured forth spontaneously when he died last year. She has further cause for pride in the fact that the example set by her parents is being closely followed by our young Queen, to such an extent, indeed, that pleas have been voiced that she should not be burdened with an excessively heavy list of public engagements.

Two of the greatest periods in British history have coincided with the reigns of Queens—Elizabeth I and Victoria—and already there is talk of the new Elizabethans as if the mere presence of a Queen upon the throne automatically ushers in another era of glorious progress. But that won't come about without strenuous efforts on the part of each and every one of us, and it is to the Queen that we look, and not in vain, for inspiration. Was it just coincidence that 30 years of struggle to climb Mount Everest should culminate in success this year? As the *New York Times* put it ". . . Anyone who tries to tell us that some mere fortuitous combination of weather and material circumstances brought about the triumph at Mount Everest on the eve of Queen Elizabeth's Coronation might just as well save his breath. This was an omen. As long as men live, as long as there are pages to record the chronicles of the human race, it will be set down that man completed his conquest of the world while a young woman was preparing for consecration as Queen of England. Hillary, the New Zealander, along with Tensing, the Sherpa, 'Tiger of the Snows,' will take his place with Sir Walter Raleigh and Sir Francis Drake. While such men serve the monarchs of England one need not worry about the decline and fall of the British Empire."

In all, some 15 climbers have lost their lives in attempts on Everest, and in view of the fact that no material advantages accompany its conquest, the less adventurous of us may wonder why the attempts have gone on for so long. Mallory, who perished in the final assault on the summit in 1924, put the answer in a nutshell: "Because it's there." It is strange to think of it as no longer "there," but man inspired with a spirit of adventure has never wanted for targets to aim at, and although the highest point has now been reached, there are still several peaks higher than 28,000 ft. in the Himalayas, some of them possibly presenting even greater difficulties than Everest as a challenge to him.

Just as Hillary and Tensing could never have reached the summit without the support of the rest of the team of climbers and porters, so this country cannot play its part in the world on the strength of isolated feats of courage and endurance. What is needed is a sustained effort from each of us, whether we be technologists, technicians, skilled tradesmen, or labourers—for although a new design of aircraft, a new process, or a new textile fibre may stem from one man's genius, the transition from idea to practical reality involves a whole team of supporting workers, and failure of any one to pull his weight cannot but affect adversely the whole project.

In offering to Her Most Gracious Majesty Queen Elizabeth II our loyal greetings on the occasion of her Coronation, let us, therefore, resolve to show that same spirit of adventure, tenacity of purpose and capacity for endurance as characterised Raleigh, Drake and Frobisher, and so to ensure that the new Elizabethan Age shall make its mark in our country's history as one of continued progress and prosperity.

In the Coronation Honours List

KNIGHT BACHELOR

Edward C. Bullard, Director, National Physical Laboratory, Department of Scientific and Industrial Research.

Sydney Camm, C.B.E., Director and Chief Designer, Hawker Aircraft, Ltd.

Ernest W. L. Field, C.B.E., Director, Scottish Engineering Employers' Association.

Andrew Naesmith, C.B.E., J.P., General Secretary, Amalgamated Weavers' Association (A member of the Iron and Steel Board).

Stanley W. Rawson, Director-General of Machine Tools, Ministry of Supply.

Thomas O. M. Sopwith, C.B.E. For services to aircraft production.

K.C.B.

Sir John D. Cockcroft, C.B.E., Chairman, Defence Research Policy Committee and Scientific Adviser to the Minister of Defence. Director, Atomic Energy Research Establishment.

Robert Cockburn, O.B.E., Scientific Adviser to the Air Ministry.

Ernest T. Jones, O.B.E., Principal Director of Scientific Research (Air), Ministry of Supply.

K.B.E.

Sir Grenville S. Maginness, Chairman, Churchill Machine Tool Company, Ltd., Manchester.

Sir Frederick E. Rebbeck, J.P., D.L., Chairman and Managing Director, Harland and Wolff, Ltd., Belfast.

Professor Hugh S. Taylor, Professor of Chemistry and Dean of the Graduate School at Princeton University, U.S.A.

C.B.E.

E. B. Ball, Managing Director, Glenfield and Kennedy, Ltd.

F. S. Barton, Principal Director of Electronic Research and Development, Ministry of Supply.

R. W. Cheshire, Deputy Chief Scientific Officer, Admiralty.

N. A. Gass, M.C., a Managing Director, Anglo-Iranian Oil Company.

J. E. Hurst, J.P., President, British Cast Iron Research Association.

Col. B. H. Leeson, O.B.E., T.D., Director of British Electrical and Allied Manufacturers Association, Inc.

C. W. Moss, Director, Vickers-Armstrongs, Ltd.

D. A. Oliver, Metals Economy Adviser, Ministry of Supply.

R. B. Southall, Director and General Manager, National Oil Refineries, Ltd.

J. Summers, O.B.E., Chief Test Pilot, Vickers-Armstrongs, Ltd.

O.B.E.

Wing Commander R. P. Beamont, D.S.O., D.F.C., Chief Test Pilot, English Electric Company, Ltd.

A. J. Bowron, Managing Director, F.N.F., Ltd.

W. Buckie, Technical Manager, Swan, Hunter and Wigham Richardson, Ltd., Wallsend-on-Tyne.

J. G. Bullen, General Manager, Highland Reduction Works, British Aluminium Company, Ltd.

C. F. Burden, Deputy Director, Aeronautical Inspection Services, Air Ministry.

A. L. Cochrane, Chairman and Managing Director Cochrane and Sons, Ltd., Selby.

R. Cousland, Shipbuilding Manager, J. Samuel White and Company, Ltd., Cowes.

H. J. Curnow, Assistant Director, Aircraft Production Supplies (Materials), Ministry of Supply.

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A. Logan, Technical Manager, Marine Administration, Anglo-Saxon Petroleum Company, Ltd.

J. C. Needham, Chairman, Evershed and Vignoles, Ltd., London.

C. M. Spielman, M.C., Managing Director, Whessoe, Ltd., Darlington.

J. H. Wigglesworth, General Secretary, Iron, Steel and Metal Dressers' Trade Society.

C. T. Wilkins, Assistant Chief Designer, De Havilland Aircraft Company, Ltd.

M.B.E.

A. Anslow, Production Manager, Joseph Sankey and Sons, Ltd., Wellington, Shropshire.

E. B. Babler, Chief of Metallurgical and General Research Laboratory, Allen West and Company, Ltd., Brighton.

A. Baxter, Assistant Manager, Shipbuilding Department, Vickers-Armstrongs, Ltd.

A. H. Blackwell, Director and Works Manager, David Brown Companies.

J. Bryce, Manager, Shipyard Plant Department, Harland and Wolff, Ltd.

A. H. Carding, Works Director, Smart and Brown (Machine Tools), Ltd.

R. N. L. Clarke, Plant Manager, Imperial Chemical Industries, Ltd., Alkali Division.

C. S. Hitchin, Resident Geologist, Tanganyika Coalfields and Iron Investigation, Colonial Development Corporation.

W. J. Hobbs, Works Manager, Drayton Regulator and Instrument Company, Ltd.

G. King, Senior Research Chemist, Albright and Wilson, Ltd.

R. H. Linnell, Factory Superintendent, British Thomson-Houston Company, Ltd.

J. MacGregor, Works Manager, Thermotank, Ltd.

F. Moss, Maintenance Superintendent, Garringtons, Ltd.

R. C. Mundy, Bulk Contracts Manager, Ericsson Telephones, Ltd.

F. Pearson, Manager, Heavy Duty Cooking Apparatus Department, Wm. Green and Company (Ecclesfield) Ltd.

G. A. H. E. Poole, Factory Manager, Joseph Lucas, Ltd.

J. R. Reed, Branch Accountant and Office Manager, English Electric Company, Ltd.

H. N. Scott, Manager, Outside Engineering Department, Harland and Wolff, Ltd., Glasgow.

T. A. Smith, Chief Engineer, Alley and MacLellan, Ltd.

J. S. Thompson, Chief Metallurgist and Production Manager, Durham Chemicals, Ltd.

H. Turner, Foundry Manager, International Combustion, Ltd.

F. G. V. Vincent, Plant Engineer, Supermarine Works, Vickers-Armstrongs, Ltd.

F. B. Wilson, Technical Adviser, Guest, Keen and Nettlefolds (Midlands), Ltd.

continued on page 299

Nickel in Electronics

By K. Jackson,* B.Sc., A.I.M., and
R. O. Jenkins,† A.R.C.S., D.I.C., F.Inst.P., Ph.D.

The relative importance of mechanical, thermal, electrical and magnetic properties of a metal depend on the purpose for which it is to be used. Nickel and its alloys meet satisfactorily the peculiar combination of properties called for in the construction of many components of electronic valves and similar equipment.

THE manufacture and operation of thermionic valves impose special requirements upon the materials used in their construction. The various electrodes comprising the valve assembly, the pinch and lead-in wires through the glass envelope, and the getter used in the production and maintenance of the high vacuum, have widely differing functions, each of which requires separate metallurgical consideration. With few exceptions either nickel or a nickel alloy can be found to satisfy these diverse requirements; for certain purposes in valve construction there are no satisfactory alternatives[1, 2].

As the manufacture of valves and cathode ray tubes demands closer control of purity and alloy composition than is usual for other applications, it was felt that a paper explaining the metallurgical problems in valve construction, and how they were being met, would be of interest and help both to those engaged in making the valves and to those seeking to provide the metals required. This paper has, therefore, been prepared by collaboration between the valve engineer and the metallurgist.

General Requirements for Metals Used in Valve Construction

It is obvious that any metal used in valve construction should allow fabrication of the components by mass production methods. This implies that the metal should, in general, be ductile and capable of being formed by the usual processes of metal working. Scarcely less important is the property of spot-welding readily to itself and other metals used in manufacture, since this permits the rapid assembly of components without the introduction of other and, perhaps, deleterious metals. Nickel fulfils the above requirements admirably, since it is readily cold worked and can be spot-welded both to itself and to molybdenum and tungsten. These properties are shared by many alloys containing nickel as a base.

Nickel offers considerable resistance to corrosion under normal atmospheric conditions. The problems of storage of large numbers of components are, therefore, much reduced, compared with iron or steel parts, for example. Similarly, the heat treatment of nickel is simplified because of the ready reducibility of nickel oxide in hydrogen, even in the presence of water vapour.

Many components in valves are heated to high temperatures during manufacture or in service. This is particularly true of the cathode, which may run at temperatures in excess of 1,800° C. for the "bright-emitter" types. The only satisfactory metals which can be employed are the refractory group, and the use of tungsten is universal. For the alkaline-earth coated cathode, the usual operating temperature lies between 700° C. and 800° C. and the cathode structure must be capable of withstanding this temperature indefinitely without dimensional change or sagging. In addition, the cathode may be heated to 1,100° C. for a short period during manufacture and must be able to withstand this treatment. Although the demands upon other components are not so stringent, it is necessary that they should not distort or sag during the sealing-in operation, nor during the high-temperature out-gassing of the electrodes which is employed to remove the traces of gas which would otherwise interfere with valve operation.

The melting point of pure nickel is 1,453° C. and the boiling point is 2,700° C. Its strength is adequate to meet the normal requirements for valve parts running at 800° C. under low loads, and for short periods will withstand the higher activation temperature. At temperatures above 1,000° C. the vapour pressure is sufficiently high to cause deposition of nickel films on cold structures, but this usually becomes serious only where the temperature is maintained for a considerable length of time.

Gases in Nickel

The problem of gases in metals is of great technical importance to the valve industry, since metal parts at elevated temperatures, or subjected to electron bombardment, may liberate gas in the sealed-off system and thus interfere with the normal operation of the equipment. A reversal of these conditions occurs in hydrogen thyratrons where absorption of the hydrogen may take place.

A study has been made of the gases capable of liberation from nickel.[3] The results may differ widely, because of different methods of production and fabrication, and traces of grease or oxide at the surface may increase the effective gas content by a large factor. When care is taken to avoid surface contamination, the gas derived from the body of the nickel is found to be principally hydrogen and carbon monoxide, with smaller amounts of carbon dioxide. Hydrogen diffuses rapidly through metals even at low temperatures, and this is particularly so in the case of nickel. Carbon monoxide and dioxide do not exist as molecules in nickel, but are formed at the nickel surface, to which oxygen and carbon atoms, present in solution in the nickel, diffuse and then react. The removal of carbon monoxide from nickel is a slow process requiring temperatures of the order of 1,000° C. for its completion.

* Research Laboratories of the G.E.C., Wembley.
† Research Staff of the M.O. Valve Co., Ltd., at the G.E.C. Research Laboratories.

1 E. M. Wise, *Proc.I.R.E.*, 1937, **25**, 6, 714.
2 J. Challensonnet and R. Champlin, *Rev. du Nickel*, 1950, **16**, 61.
3 C. J. Smithells and C. E. Ransley, *Proc. Roy. Soc.*, 1936, **155A**, 195.

It is desirable, therefore, to limit the amount of carbon monoxide which can be formed, by the use of nickel of low oxygen and carbon contents. Since the diffusion of hydrogen in nickel is rapid, and is appreciable at temperatures as low as 500° C., it is possible to "de-gas" nickel in hydrogen gas at high temperature, using a low temperature treatment in high vacuum subsequently to remove hydrogen during processing of the valve. A typical analysis for the gas obtained from nickel is given in Table I.

TABLE I.—GAS FROM COMMERCIAL NICKEL.
(99·14% purity, degreased 1 mm. wire).

Gas	Amount ml./100 gm.
Hydrogen	0·43
Carbon Dioxide	1·81
Carbon Monoxide	0·22

Cathodes

It is convenient to classify the application of nickel to valve components according to the particular part in which it finds application. (Table II). Two main classes of oxide-coated cathode exist, those which are indirectly heated by a heater electrically insulated from the cathode proper, and the directly heated type in which a current is passed through the cathode to raise it to the operating temperature. Both types rely upon the thermionic emissive properties of the activated oxide coating, and the fact that nickel, although inert to barium and strontium oxides, acts as an efficient carrier for the agents responsible for activation. Special metallurgical problems in the directly heated cathode merit separate descriptions of these systems.

Indirectly Heated Cathodes

Since the indirectly heated cathode is usually operated from A.C. power supplies, where a relatively large thermal mass is an advantage and power consumption is not of major importance, it is possible to design the cathode structure adequately so that it is located under low stress by insulating supports such as punched mica discs. The nickel shell acts as a conducting support to the oxide coating. Very pure nickel is not generally suitable as a cathode material because the initial development of thermionic emission depends largely on small amounts of "activating agents" present in the nickel. At high temperature, these agents chemically reduce a small amount of barium oxide to the metal, thus providing the free barium necessary to activate the barium/strontium oxide emitting surface. It has been shown that interaction between the activator and the coating does in fact take place, since a compound is often formed between the coating and metal. Typical elements which can be used as activating agents are: magnesium forming a magnesia interface, silicon giving barium silicate, titanium the titanate, and aluminium the aluminate. Of the above metals, magnesium is the most commonly employed, in amounts of 0·05–0·15%. Magnesium has the highest rate of activation of the group and the magnesia interface does not appreciably alter the thermal emissivity of the coated cathode, so that its temperature for a given power input is similar to pure nickel. Silicon, a somewhat slower activator, forms a relatively thick interface which tends to become an insulator when no anode current is drawn. The use of silicon-nickel is not advised in those applications where the valve must operate for considerable periods particularly in the stand-by condition, for example in computers, since the interface resistance may grow sufficiently large as to interfere with operation. For mercury-vapour-filled valves, however, the formation of the silicate interface may be of advantage, since it appears to protect the underlying nickel from attack by mercury while the valve is in storage. The properties of the interface compound, and their relation to valve performance, have been reviewed in a recent paper.[4]

Where the nickel for cathode manufacture contains an element used as an activating agent, it is necessary to specify the composition limits carefully, since too low a concentration will slow the activation process, while an excess may result in trouble due to the formation of excess barium, heavy interface formation, and, for magnesium, the evaporation of magnesium films on to the surrounding electrodes. Work is continuing on the various activators, and a recent publication in the U.S.A. has advocated the use of about 0·1% aluminium.[5]

TABLE II.—THE USES OF NICKEL IN VALVE COMPONENTS.

Use	Alloy*	Nominal Composition %
Indirectly heated cathodes ..	"O" nickel Inco "220" nickel (U.S.A.)	99·5 min. (Ni + Co) + controlled Mg.
Directly heated battery operated cathodes	0·25% magnesium nickel	As stated.
Directly heated battery operated cathodes	0·4% aluminium nickel	As stated.
Directly heated cathodes (50 mA. range)	N.93	2 W, 1 Al, 0·2 C, balance Ni.
Directly heated cathodes (50 mA. range)	N.100	2 W, 1 Al, 0·2 C, 0·2 Mg, balance Ni.
Mercury rectifier cathodes ..	Cobanic	40 Co, 0·2 C, 0·2 Si, balance Ni.
Anode support wires	"A" and "G.F.A." nickel	99·0 min. (Ni + Co).
Grid winding wires and grid side rods	5% manganese nickel	4·5–5·5 Mn, balance Ni.
C.R.T. gun electrodes and deflection plates	Nickel-copper	45 Ni, 55 Cu.
Valve springs	Nimonic 90	15–21 Co, 18–21 Cr, 5 max. Fe, balance Ni.
Glass-to-metal seals		
Soft glass	"Dumet" (copper-clad)	41–43 Ni, balance Fe alloy, clad with 30 Cu.
Soft glass	Nickel-iron	49–51 Ni, balance Fe.
Soft glass	Nilo 475, No. 4 alloy, etc.	42–47 Ni, 4–6 Cr, balance Fe.
Borosilicate glass	Nilo K, Kovar, Nicosel, etc.	28–30 Ni, 16–18 Co, balance Fe.

* Some of these materials are described by trade marks.

Effect of Impurities

While the presence of the activating agent in small amounts is important for the satisfactory production of emission, certain other impurities are deleterious and may, in fact, completely poison the emission. The two principal impurities whose presence is known to produce a serious effect upon emission are chlorine and sulphur. The catastrophic fall in emission may be analogous to the effect of traces of impurity upon the conductivity of semi-conductors. It has been found that 0·02% sulphur in the nickel is sufficient to reduce the emission below a workable value. Chlorine is not likely to be a contaminant of nickel, except by corrosion due to atmospheric contamination and chlorine-containing degreasing agents which have been allowed to become acidic. Sulphur is a common impurity in metals and it has been found necessary to specify a maximum sulphur content of 0·005% for nickel used in cathode manufacture.

4 D. A. Wright (paper in preparation).
5 A. M. Bounds and T. H. Briggs, *Proc.I.R.E.*, 1951, **39**, 788.

Although every care is taken by the alloy manufacturer to meet the specification for sulphur content, it is not generally realised by either the user or the manufacturer whose business it is to process the nickel, that sulphur contamination may occur at any stage where the hot metal can be brought into contact with sulphur-containing gases.

Although the presence of magnesium and manganese may offer some protection and the attacked layer may be superficial, so that the mechanical properties of the nickel are not impaired, the presence of sulphur may have considerable effect upon thermionic emission of the cathode. Usually the effect, where emission is reduced, is sufficiently specific for the cause of the trouble to be known, but the damaging effect of sulphur may take another form when present at the internal surface of the cathode. The insulating properties of the alumina between the heater and cathode may be reduced, with resulting heater/cathode leakage, the insulation often being reduced by a factor of 100. The presence of sulphur contamination may be caused by the incomplete removal of sulphonated drawing oils before annealing, but it is more often caused by leakage of sulphur-containing gases from gas-fired annealing furnaces into the furnace chamber containing the charge. The use of an inner tube, separated from the furnace tube proper, is insufficient guarantee of freedom from sulphur attack, since this tube itself may be attacked and serve as a source of sulphur. The best safeguard against this trouble is the use of electric furnace heating with a cracked ammonia or hydrogen atmosphere to protect the charge. Where gas heating is necessary, every care to remove surface-attacked metal during manufacture and the regular checking of heat-treatment equipment for leakage is required.

Composition Limits

Nickel prepared for indirectly heated cathode use is generally given the designation "O" nickel in the United Kingdom. Electrolytic nickel is usually employed as a basis for manufacture, since this material is of high general purity. A small amount of cobalt is always present but this has little effect upon the cathode performance. Iron is usually present and this has not been shown to produce any effect in quantities less than 0·2%. The limits of impurity for typical "O" nickel and the equivalent "220" nickel used in the U.S.A. are given in Table III.

As stated above, the magnesium content must be carefully specified and the usual limits for this element are 0·07–0·15%, although in many applications a top limit of 0·1% is desirable. It is probable that part of this may be present as oxide or nitride and is, therefore, not available to the cathode for activation. No chemical methods are available for the determination of free magnesium present in cathode nickels, but a recent paper has described a method for the separation of free magnesium from cathode nickel by evaporation from an electrically heated sample under high vacuum.[6] Experimental work carried out at the Research Laboratories of The General Electric Co., Ltd., suggests that this method may be satisfactory for thin-walled samples, where diffusion of magnesium to the surface can take place rapidly, but for larger samples vacuum fusion would be necessary to ensure complete removal of the magnesium. Further work is required to ensure that no reduction of magnesium oxide or nitride takes place, and that the removal of magnesium is not limited by the evaporation of a nickel-magnesium alloy of constant composition.

TABLE III.—COMPOSITION LIMITS FOR "O" NICKEL AND "220" NICKEL.

	"O" Nickel %	"220" Nickel %
Nickel + Cobalt	99·5 min.	—
Copper	0·1 max.	0·2 max.
Iron	0·2 max.	0·2 max.
Manganese	0·15 max.	0·2 max.
Carbon	0·04 max.	0·08 max.
Silicon	0·01–0·10	0·05–0·07
Sulphur	0·005 max.	0·008 max.
Magnesium	0·07–0·15	0·01–0·10

The physical properties of "O" nickel are given in Table IV.

Little attention has been given until recently to the physical nature of the cathode surface, although it is certain that this plays an important part in determining the adhesion between the nickel and the coating. While the chemical cleanliness of the surface is of the utmost importance, a smooth highly-polished surface, produced, for example, by electropolishing, is unsatisfactory, since there is no keying between the coating and the metal. Usually the valve manufacturer has met problems of coating adhesion by variation in coating techniques, but a more satisfactory answer could be obtained if methods were available for the production of a clean and slightly roughened surface on the nickel tubing or sheet during manufacture. There is evidence that at least one American manufacturer is attempting a solution to the problem along these lines.

Directly Heated Cathodes

The directly heated cathode is used where insulation between the heater and cathode is unnecessary, as in many rectifier valves, or where the heating current is drawn from storage or dry cells. In the latter case, it is necessary to keep the power supplied to the heater to a minimum, and this can be achieved in the directly heated cathode by using a thin wire or ribbon to give a low thermal mass and high resistivity. The rigidity of the cathode is maintained by spring tension, and for the 0·4 V. 50 mA. valves designed to run from a dry cell, the cathode consists of a wire 1 in. long and 0·001 in. diameter, weighing 0·1 mg. and kept at a tension of 0·5 g. The tension applied must be adequate to avoid microphony, i.e., filament vibration due to mechanical disturbance of the valve, and the operating temperature high enough to give the necessary emission. The alloy used for this purpose must be capable of giving a satisfactory mechanical life under these conditions, in addition to fulfilling emission requirements similar to the indirectly heated cathode.

It will be seen that a directly heated cathode has to meet conditions similar in many respects to the creep-to-rupture tests used for the examination of metals for

TABLE IV.—PROPERTIES OF "O" NICKEL.

Melting point	1,435–1,445° C.
Density	8·9 gm./cc.
Specific heat	0·13 cal./gm.
Coefficient of expansion	13×10^{-6} in./in./° C.
Electrical resistivity at 20° C.	9·5 microhm/cm.^{3}.
Electrical resistivity temperature coefficient	0·004–0·005 ohm/ohm/° C.
Tensile strength	50,000–80,000 lb./sq. in.
Yield point (0·2% offset)	10,000–30,000 lb./sq. in.

6 S. Kitahara, *J. Scient. Res. Inst.* (Japan), 1951, **45**, 199.

use in high temperature service. For the case quoted above, the temperature is about 800° C. and the operating stress of 0·7 tons/sq. in. would not be considered onerous in high temperature turbines for example. There is a major difference, however, in that the normal engineering structure contains many grains in its cross-sectional area. For the filament of a directly heated cathode, the grain size can be of the same order as the wire diameter, so that the wire may become effectively a series of single crystals placed end to end.[7] Creep and failure for a system of this type may bear no relation to the results obtained on large polycrystalline specimens, although stress and temperature still have a profound effect upon the time-to-failure for the wire.

The effect of surface conditions on wires of small diameter can also be very marked, and the nature of the interface between the coating and core can alter the time-to-failure very appreciably. Because of the relative amount of surface and the number of grains in the cross-section, the time-to-failure of the filament is dependent upon the cross-sectional area, and increases markedly as this is increased for given stress and temperature conditions.

Alloys Used

Pure tungsten and alloys based on nickel have been used as core materials for directly heated cathodes. Tungsten has the advantage of remarkable strength at high temperatures, which removes any difficulties due to filament breakage. The emission results are not usually as satisfactory as in the case of nickel alloys, however, and its low resistivity and high thermal conductivity introduce difficulties in design, because of system length or because the wire diameter required is much smaller than that of a corresponding nickel alloy.

For valve types with a higher rating than 50 mA., it is possible to make use of alloys which are essentially nickel with the addition of an activating agent. The percentage of the latter is usually greater than is used in indirectly heated cathodes, since the ratio of coating to core weight is higher. Typical alloys which have been used for the 100 mA. cathodes include those containing respectively, 0·4% aluminium and 0·25% magnesium. For still higher ratings, "O" nickel is employed, except for mercury-vapour rectifiers where nickel-silicon or nickel-cobalt-silicon is preferred. Although these materials are satisfactory for the applications given, their life performance and hot resistivity are inadequate to meet the requirements of the lower rating valves, which need smaller diameter wire. Certain directly heated valves with high-wattage filaments need short filamentary cathodes, due to design considerations, and these call for high-resistance alloys to keep the filament length to a minimum. In these cases a nickel alloy containing 20–40% cobalt has been found suitable.

The range of alloys for use in the small battery-operated valves is seriously limited by the necessity for producing and maintaining a satisfactory thermionic emission. The choice of alloying additions is, therefore, limited to those which have been proved to have little or no effect upon the emission. Elements such as chromium and molybdenum, which have a pronounced strengthening effect upon the nickel lattice, are unsuitable because of the formation of undesirable interface compounds. Titanium, silicon, magnesium, aluminium or zirconium may only be added in small amounts, since larger quantities will either over-activate the coating or form a heavy interface layer with damage to the emission. The metals which can be alloyed with nickel in substantial amounts are limited to tungsten and cobalt, both of which have an extensive solid solution range in nickel. Smaller quantities of activating agents can be added to improve the emission performance or to increase the life performance, but these minor constituents must be carefully controlled for the reasons given.

Aluminium-Tungsten-Nickel Alloys

The N.93 alloy, which finds use in directly heated filament cores, is a nickel alloy containing 2% tungsten, 1% aluminium and 0·2% carbon. The alloy is prepared, as described in the patent,[8] by melting nickel in air and deoxidising it with carbon to leave the preferred amount of carbon present, the remaining constituents being then added and the melt cast.

The alloy shows good working qualities and can be rolled, swaged and drawn to 0·001 in. wire required for the 50 mA. rating valves. The good performance of this alloy is claimed to be due to the presence of tungsten carbide in the alloy, with consequent increase in life at high temperatures. Life tests of the alloy in valves confirm its value where the coating is applied as a sludge and sintered on to the wire at high temperature. The results using coatings applied by cataphoresis not involving high temperature treatment are not so satisfactory. The core coating interface formed when drag coating is employed may have a beneficial effect.

The alloy N.100, a development of N.93, has the composition 2% tungsten, 1% aluminium, 0·2% carbon, 0·2% magnesium, and the remainder nickel. The addition of 0·2% magnesium to the N.93 alloy composition results in a considerable improvement in the life performance of the filament: a further advantage is gained in an increased rate of activation. It is difficult to explain the improved life on the basis of the presence of tungsten carbide, and alloys have been made omitting the 0·2% carbon from N.100 with no appreciable effect upon the life for a given operating temperature. From measurements of the cold resistivity of these alloys, it can be inferred that the carbon is in solid solution in the alloy, and that any improvement that it may confer is due to its marked effect upon the cold tensile strength and resistivity. For given cathode dimensions and coating, the carbon-containing alloy will run 10–15° cooler than the carbon-free material, and this must be taken into consideration in assessing the merit of the two alloys. An alternative explanation for the advantageous properties of these alloys may be the presence of finely divided oxides distributed throughout the structure. This is likely to occur with alloys containing constituents which form stable oxides, and particularly so for magnesium. It is known from work on both nickel and tungsten that the presence of such oxides, even in amounts of 0·01%, will limit the grain growth in the metal so that there are usually several grain boundaries in any transverse section of the wire.[9] This would eliminate one type of failure found where a grain boundary crosses the wire. Slip may occur between the two grains along this boundary with a rise in stress at this point and, as a result, further slip continues till failure. This "offset" failure is usually

7 C. E. Ransley, *J. Inst. Metals*, 1932, **48**, 287.

8 Widell, British Patent No. 587,931.
9 C. E. Ransley, British Patent No. 580,744.

found in regions of temperature gradient, where grain growth is likely to occur, and has been observed on nickel, pure aluminium-nickel, and aluminium-tungsten-nickel alloys: it has not been found in those containing magnesium. The presence of oxide may have some effect upon a second type of failure which occurs exclusively in the high temperature region of the wire, and is responsible for the majority of failures in N.100 filaments. It is possible that the considerable variations in performance between batches of N.100 may be due to variation in oxide content.

The manufacture of alloys for filament wires is unusual in that the quantity of metal required is small; most of the cost of manufacture going into the drawing of the alloy to fine sizes. It is, therefore, advantageous to use processes which give close control of the alloy composition, or which confer beneficial properties on the finished wire. Powder metallurgy methods offer decisive advantages, and both production and research on these materials have been based largely on these methods at the Research Laboratories of The General Electric Co., Ltd.

The further development of alloys for use in directly heated filaments largely rests upon a better understanding of the mechanism of failure, and upon the important part that the coating-core interface and finely dispersed oxides play in determining the filament life. Although the nickel-aluminium-tungsten-magnesium alloy has given satisfactory service for the 0·023 mm. filament size, present trends in battery valves call for smaller wire diameters to meet the lower filament ratings. There is no guarantee that this alloy will be capable of fulfilling the more onerous conditions, nor does the material appear capable of giving a satisfactory life at coating temperatures in excess of 800° C. with spring tensions necessary to avoid microphony.

Anode Materials

While the choice of the material for the anode in most valves does not depend upon such critical factors as are required for the cathode, it is necessary that the metal used should be capable of withstanding temperatures of 800° C. without sagging, should possess a low gas content, and should be readily degassed during pumping. In the higher rating valves, considerable heat may be developed at the anode, and this must be dissipated by radiation, so that the outer surface should be rough and blackened to improve its radiating efficiency. Nickel fulfils these requirements admirably except for the last provision, and it is necessary to reduce the anode temperature by specially coating the surface to produce the matt black surface required. This surface usually consists of carbon, which has a radiating efficiency of 80% black body compared with 20% for bright nickel.

The purity of nickel required for the anode is generally not so high as that required for the cathode. Nevertheless, if volatile impurities are present, they may reach the cathode and poison it. Contamination with sulphur may be a source of trouble introduced during an annealing treatment in gas-fired furnaces or by sulphur lubricants.

The ratio of nickel used in anode construction to that used in cathode manufacture is high and, because of the shortage of nickel, attempts have been made to find alternative materials. The most promising of these is aluminium-coated iron, which is prepared by rolling together aluminium and pure iron sheet, the surfaces of which have been suitably cleaned and roughened. With a sufficiently great reduction in thickness, the metals cold weld, and the resulting bi-metal sheet is able to withstand forming and bending without separation. The material cannot be fully annealed because of embrittlement due to the formation of an aluminium-iron compound. This fact is, however, turned to considerable advantage, since on heating the anode to 700° C. during outgassing, formation of the compound roughens and darkens the outer surface of the anode to produce a good radiating surface. On the grounds of cost and convenience, this material will probably replace nickel as the major anode material, providing supplies become available in quantity. As a further improvement upon aluminium-clad iron, successful attempts have been made to prepare iron, clad on one side with aluminium and on the other with nickel. In operation, the cathode faces a nickel surface, while the aluminium is available for forming the radiating outer surface. By this means, the slight poisoning of the cathode due to gas released from the aluminium-iron anode surface facing the cathode may be reduced.

Large quantities of nickel and manganese-nickel wire are used as lead and support wires where considerable strength is not required. The principal advantages here, apart from questions of purity and freedom from contaminating material, are the reasonable conductivity and good spot-welding characteristics.

The wire used in the winding of the grid assemblies in receiving valves is almost always molybdenum or nickel alloy. Considerable advantages may be claimed for molybdenum because of the high strength, and also because of the very good stability to dimensional change during heat treatment and the subsequent assembly and manufacture. Its disadvantages are the high cost, brittle patches, and the ease of oxidation, which necessitates considerable precautions during sealing to avoid molybdenum oxide formation, which damages emission of the cathodes. Where possible, the use of a nickel alloy containing 5% manganese is preferred, since this alloy has a reasonable tensile strength with a low grid emission. The stress-relief temperature is lower than that of molybdenum, and there is a danger that at the "lighting" stage of the valve manufacture, the grid may reach a sufficiently high temperature to cause distortion due to relief of residual stress, and the conductance of the valve may thus change. The side rods of the grid are usually made of pure nickel or manganese-nickel, unless the grid temperature is sufficiently high to give trouble by grid emission, when copper or chrome-copper is preferred because of the higher thermal conductivity, which enables the heat to be conducted away to radiators and to the foot tube.

The electrode systems of cathode ray tubes form a special case, where these are fitted with magnetic deflection systems. Nickel is here unsuitable, since it is ferromagnetic, and use is generally made of the 45–55 copper-nickel alloy which is non-magnetic.

Glass-to-Metal Seals

The construction of the thermionic valve and cathode ray tube depends wholly upon methods of sealing metal conductors to the glass envelope without introducing leaks into the system. As a result, a wide range of alloys has been developed, each suitable for a certain type of application.

The general characteristics required for metals for sealing to glass are that they should be readily produced in quantity to a definite thermal expansion curve. This limits the use of materials such as platinum and tungsten to applications where special requirements justify the increased cost and difficulty in manufacture. The alloy should be ductile, and in its processed form should be free from metallurgical defects such as slag lines, laps or cracks, since these are often responsible for leaky seals. It is also desirable that the gas content of the material should be low, since this gas is evolved during seal making and may be responsible for poor quality sealing. Good thermal and electrical conductivity is an advantage, since strain can be set up in the seal due to electrical heating of the metal. Any oxide formed during the sealing operation should adhere firmly to both the metal and the glass.

Since the thermal expansion of the alloy is sensitive to small variations in composition and impurities, and to the heat treatment given, the control of the manufacture of these materials must be of a high order. Alloys are usually prepared by high-frequency furnace melting, although material prepared by powder metallurgy has given very satisfactory results when care has been taken to eliminate any heterogeneity due to the manufacturing process.

Glass-to-metal seals may be divided into two classes, those types where the expansion of the glass and metal differ widely, and those where an attempt is made to match the two expansions to minimise strain in the seal. In the first class, yielding of the metal is relied upon to reduce strain. For this reason, metals of low yield point, such as copper, are preferred, and yielding at the metal is assisted by careful seal design. Typical of this class are molybdenum-silica and copper-glass seals. In the second group, the use of any particular alloy is limited to those glasses of similar expansion properties. It should be noted that the expansion of a glass is not in general linear with temperature as for many pure metals, but increases markedly at a temperature associated with the lower annealing point of the glass. It is important, therefore, that any sealing alloy should show an expansion curve as close as possible to that of the glass at all temperatures up to the upper annealing temperature.

Nickel-Iron Alloys

Alloys of iron containing nickel in amounts of 30–50% show a wide range of expansion coefficients, which might be expected to match those for both soft and hard glasses. The binary alloys are, however, unsuitable for sealing to borosilicate glasses, since it is not possible to meet the required conditions of a low initial expansion followed by a rise over the same temperature range as the glass. The effect is less marked for the higher nickel contents, and these alloys are suitable for sealing to lead or soda glasses: the usual range of composition is 48–52% depending on the glass. Difficulties in the use of these alloys are caused by poor adhesion of the oxide to the metal, but this trouble may be reduced by a thin electroplated layer of copper. A further use of the nickel-iron alloys is in "Dumet" wire, which consists of a 43% nickel-iron core plated to 30% of its weight with copper and then drawn. This material is widely used in receiving valve manufacture and in the lamp industry.

By the addition of a third component to the nickel-iron alloys, their properties can be modified to make possible their use for sealing to 'hard' glasses. The introduction of cobalt into the alloy results in a lowering of the thermal expansion, with little change in the temperature at which this begins to increase rapidly. By suitable choice of composition, it is possible to produce alloys whose thermal expansion is close to that of certain borosilicate glasses over a range of 450° matched to F.C.N. glasses. These alloys are manufactured under various trade names, such as Nilo K, Kovar, Nicolsel and Versilex. They are widely used in valve manufacture, particularly for high power water-cooled valves.

The percentage of cobalt which can be used in these alloys is limited by the metallurgical stability of the alloys. It is necessary to retain the gamma phase in these materials since a marked increase in the expansion occurs when the alpha phase is formed. For this reason, it is desirable to heat treat cold-worked material above 900° C. to ensure that it is fully in the gamma form.

The presence of chromium in nickel-iron alloys results in an increased thermal expansion coefficient. This has led to the development of chromium-containing alloys for sealing to "soft" glasses, for example a 6% chromium, 42% nickel-iron alloy suitable for seals with lead glass, as an alternative to "Dumet." Pins of this material, often known as No. 4 alloy, are sealed through the moulded glass bases of many modern receiving valves. Care is necessary, however, to ensure, by an appropriate heat treatment, that a suitable adherent oxide is formed on the surface of the pin before it is sealed into the moulded base.

Iron alloys containing up to 26% chromium are suitable for sealing to soft glasses. The chromium content results in the formation of very stable oxide films on the metal surface which afford considerable protection at high temperatures. The low electrical conductivity and the difficulty in removing the oxide film for spot welding and making electrical contact are disadvantages in these materials. Their stiffness when used as pins for moulded valve bases can also cause cracking of the glass if the pins are strained.

Acknowledgments

The authors wish to thank Messrs. Henry Wiggin & Co., Ltd., and The Mond Nickel Co., Ltd., for their interest throughout the preparation of this paper. The authors also desire to tender their acknowledgments to the M.O. Valve Co., Ltd., on whose behalf much of the work described in this paper was carried out.

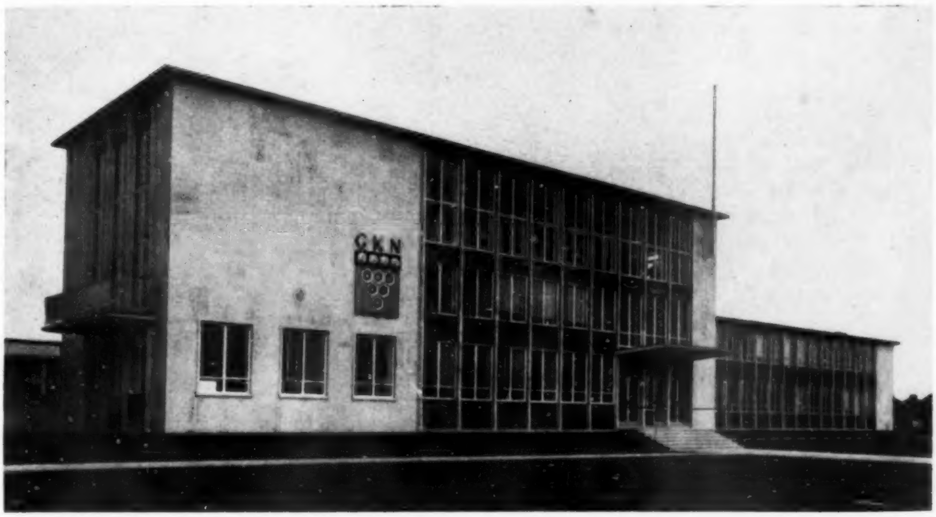
Lewcos Scottish Office

The London Electric Wire Company and Smiths, Ltd., and its Associate Companies—Frederick Smith & Co.,—The Liverpool Electric Cable Co., Ltd., and Vactite Wire Co., Ltd.—announce the opening of a Branch Office and Store at 7a, Young Street, Edinburgh.

Change of Address

The new address of Mr. D. McDermott, the Scottish Area Sales and Service Engineer of Wild-Barfield Electric Furnaces, Ltd., G.W.B. Electric Furnaces, Ltd., and The Applied Heat Co., Ltd., is 147, Bath Street, Glasgow, C.2. The telephone number will remain as Douglas 8839.

The G.K.N. Group Research Laboratory



THE formation of G.K.N. Ltd., in 1902 brought together firms whose roots went back to that remarkable period of industrial expansion which occurred in England during the first fifty years of the 19th Century. The equally remarkable expansion of the G.K.N. Group of companies in the ensuing fifty years, brought other firms of similar age and reputation into the Group. Joseph Sankey and Sons, Ltd., Garringtons, Ltd., John Lysaght's, Ltd., Exors of James Mills, Ltd., Bayliss, Jones & Bayliss, Ltd., and United Wire Works, Birmingham, are typical of the firms which now go to make up the G.K.N. Group, and, in addition to the British companies, operating units can be found in many countries overseas.

Prior to the War the research and development activities were carried out at the individual operating units, but in the period of reconstruction which followed the cessation of hostilities, the G.K.N. Board decided that a central research organisation should be created, so that some of the problems common to a number of works could be tackled more expeditiously. This laboratory was founded upon an existing organisation started by Joseph Sankey & Sons, Ltd., in 1945, primarily to pursue research into the production of electrical steels, and from 1947 until the end of 1952 was housed in buildings at various Sankey Works in the Bilston area. During this period, work was started on a completely new building situated on the main Wolverhampton to Birmingham Road, about 1½ miles from Wolverhampton.

The New Building

The building was designed by Mr. A. R. Twentyman of Lavender, Twentyman & Percy of Wolverhampton, and built by F. & E. V. Linford, Ltd., of Cannock, with C. Howard Crane & Partners of London as Consultants. It stands on approximately 9 acres of ground, thus giving ample room for future expansion.

There are three main sections: the front administrative block containing the canteen, drawing office, Director's office, conference hall and library; a two storey laboratory wing with basement; and a single storey workshop wing. A two storey section joining the main laboratory wing and the workshop area houses the materials stores and offices for senior staff, while a further section of the basement accommodates the oil fired heating plant. The total floor area is approximately 40,000 sq. ft.

Constructed of reinforced concrete, the building rests for the main part upon deep piles, the single storey wing being built on a concrete raft. Water, gas and compressed air are piped throughout the building, and in addition to the normal electrical services, points in most of the individual laboratories are wired back to a central control board, from which can be selected a wide range of both A.C. and D.C. supplies.

Staff

At the present time, the staff totals 115, of which number some 40 are graduates in various branches of science and technology. Administratively, the Laboratory is divided into twelve main sections—metallurgy, mechanical engineering, chemistry, physics, instrumentation and control, electrical engineering, mechanical construction, electrical construction and installation, operational research, liaison and information, administration, and maintenance—with the head of each section responsible to the Director of Research, Dr. T. Emmerson. The various sections are by no means watertight compartments, and many of the projects undertaken are tackled by a team consisting of members belonging to several sections.

Policy

The Research Laboratory is a part of G.K.N. Group Services, Ltd., and the Director of Research is responsible

to the Research Committee of the G.K.N. Group, which consists of representatives of the higher management of a number of the larger operating units. The Laboratory has three main functions :—

(*a*) to carry out research and development work of direct and immediate interest to Group firms on processes and materials, and to advise on and develop where required, methods of materials testing ;

(*b*) to carry out a certain proportion of long term fundamental research in fields related generally to work carried on in the Group ; and

(*c*) to provide a general laboratory service for those units of the Group which are too small to maintain their own laboratories, and to act as an information centre and clearing house for technical literature throughout the Group.

Equipment

In a brief article such as this, space does not permit of a detailed account of the extensive equipment necessary for carrying out the work of the Laboratory, an indication of which is given under the heading of work in progress. The standardised equipment has been carefully chosen for the purpose of carrying out routine day-to-day operations with efficiency and speed, but in an organisation such as this, much of the equipment is of a specialised nature. Included in the latter are the plant for the induction melting of high-purity alloys in vacuum and in air, and the small rolling mill which is at present being installed for the subsequent working of these melts. The workshop is well equipped to carry out its main function of providing necessary experimental equipment for the Laboratory, and, to a lesser extent, specialised mechanical test equipment for use in Group works. The electrical constructional workshop has provided for works use, a considerable amount of equipment for counting and electrical testing, in which sphere the Laboratory accepts responsibility for design, manufacture, installation and maintenance. The high quality of the design and constructional work has proved that electronic equipment can be designed to operate with very little trouble under the adverse conditions which frequently prevail on the shop floor.

General view of the chemical laboratory.

Melt being poured from 30 lb. induction furnace.

Work in Progress

In referring to the work in progress—and we shall deal mainly with that part which is of metallurgical interest—it should be emphasized that, in a young organisation such as this, the activities are not a full representation of the problems of the Group, since, inevitably, it has only been possible to tackle a number of the more important problems in the first instance. As the activities extend, the work is likely to become more representative.

Metal Working.

One of the most important metal working processes used in the Group is the drawing of steel wire and its subsequent fabrication into screws, nuts and bolts. An active programme on wire drawing, therefore, aims at the development of techniques which enable wire drawing to be carried out at the greatest possible speed and with the best possible control of the finished product. The subsequent cold heading operations, by which the wire is converted into finished screws, nuts and bolts, is naturally a process which is the subject of fundamental study, the information from which should provide a sound basis for future development work. This study involves experimental work to determine the forces necessary to re-shape the metal, the manner in which the metal flows during the process, and the relation of these results to the mechanical properties of the material.

The design of the high speed machinery on which heading and similar operations are carried out is a subject which involves a great deal of local working knowledge,

and is generally carried out by development units associated with the particular works concerned, rather than in the Group Research Laboratory. However, tools and dies are an important ancillary to these operations, and the Laboratory is increasingly involved with methods of tool design and manufacture, with the aim of producing tools more rapidly and more cheaply, with methods which enable the life of the tool to be increased (the lubrication methods used during the operation are of obvious importance here), and with any new materials and techniques which will assist towards this end. The high standard of performance and accuracy required can readily be upset if the material and the heat treatment to which it is subjected are not under close technical control, and here again the Laboratory is concerned to discover the best materials for the purpose and to ensure that they are properly processed.

Apparatus under development for the detection of cracks in socket cap screws and similar products. The screw is put into torsional oscillation and the time for this oscillation to decay is noted. A short decay time indicates a cracked product.

Electrical Sheet.

Some of the specialised products of the Group are also of sufficient importance to justify special attention. Silicon iron sheet for use in electrical equipment is one of the most important products of Joseph Sankey & Sons, Ltd., and a study is being made, in close collaboration with the works, of the methods of production, while more fundamental background research on the material itself is in progress. Methods of rolling and of heat treatment have received particular attention with a view to determining how the quality of the final product may be improved. More fundamental work is concerned with the iron-silicon-carbon phase diagram, and with the determination of the effects for impurities in the material. This work requires a detailed study of the best methods available of determining electrical and magnetic characteristics, and in the course of this work a number of methods have been developed which are unique, and which represent a considerable improvement on existing methods.

Experimental hot-dip galvanising unit.

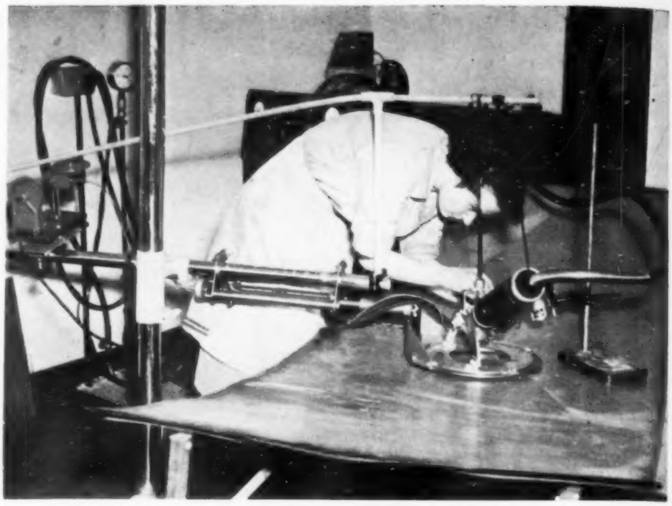
Materials Analysis and Testing.

In a Group of this type, it is important to have available accurate and rapid methods of analysis and testing, and considerable effort is devoted to the development of chemical, mechanical and physical methods of testing. A Group Committee on materials analysis meets regularly and ensures that the various local laboratories within the Group agree as to their methods and procedures, and that they are thoroughly up to date in both. The Research Laboratory is represented on a number of Committees run by Research Associations and similar bodies, and contributes usefully to their work.

Where special methods of analysis are required by Group firms, these are frequently developed by the Laboratory on their behalf, and in addition day-to-day analytical services are available to those smaller units in the Group who require such services from time to time, but who cannot economically justify the maintenance of their own facilities. In all these matters, every possible analytical and test method is called into play, ranging from the usual machines to determine mechanical properties, to the more high specialised X-ray powder techniques. Non-destructive methods of testing are the subject of active investigation for the detection of flaws and cracks in raw material and in finished components, and at least two novel methods have recently been developed.

Galvanising.

Galvanising of mild steel is an operation in use in certain works of the Group and the recent zinc shortage



X-ray apparatus for the measurement of residual strain in metals shown in operation on a sheet of transformer iron.

prompted an investigation into the process, with a view to determining the best means of reducing the coating thickness without, in any way, reducing the effectiveness of the protection it affords. In the course of this work, close collaboration has been maintained with the British Non-Ferrous Metals Research Association, who have also been studying the problem.

High-Frequency Induction Heat Treatment.

There has been increasing use in the last few years of high-frequency induction heating in carrying out heat-treatment operations, particularly in the case of mass production quantities, where one coil can be used for the treatment of large numbers of components. Apart from the fact that the plant can be inserted in the production line, the rate of heating is extremely rapid and scaling is thereby minimised. Under investigation at the present time is the heat-treatment of alloy steels of high chromium content. The results obtained to date show that the rate of carbide solution is surprisingly high, and that prolonged soaking is unnecessary to ensure complete solution of the carbides.

Works Instruments and Equipment.

One of the functions of the Group Research Laboratory is the development and manufacture of equipment for controlling works processes and for checking the finished product. For example, in any Group involved in the mass production of small components, the need to assess the number made at various stages in the process, and to batch the components for final sale, make the application of counting techniques of the greatest importance in the interests of efficiency and economy. In the course of this work, electronic techniques are widely adopted, particularly for high speed operations, but there is no tendency to regard electronic devices as the answer to every problem, and when a simple mechanical method will fill the bill it is used.

Console designed and built in the Laboratory containing the electronic energising and measuring equipment for the electrical testing of single sheets of silicon iron transformer material. This has been operating in a Group works for some time.

Mention has already been made of the importance of the magnetic properties of silicon iron sheet for use in electrical equipment, and apart from the standard tests taken to approve the material, each sheet is checked by equipment specially developed in the Laboratory. The console for this tester is illustrated here.

Operational Research.

The use of operational research techniques to provide physical data from which management can take decisions as to the way in which operations should be carried out, is a subject which has been increasingly applied since its utility was so amply proved during the last War. Such factors as the control of inspection operations by quality control methods, and the determination of the best number of operators to look after a given number of machines, are subjects of the greatest economic importance and are continually under review.

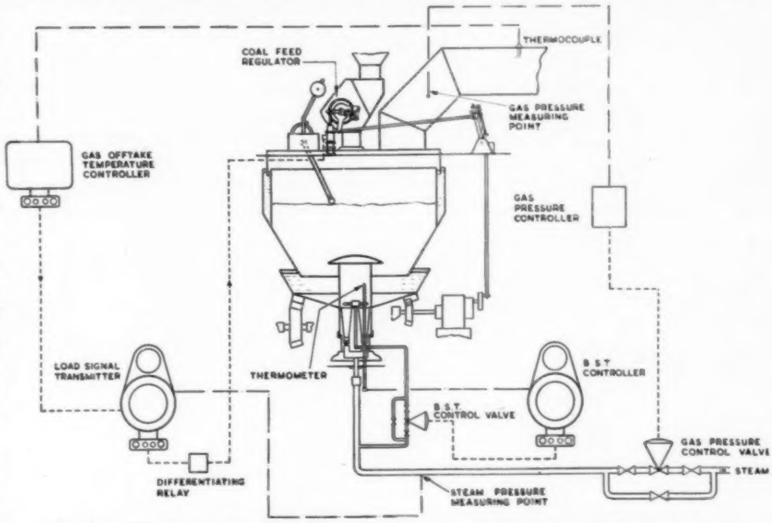
Coronation Week Visits to Helsby Works of B.I.C.C.

During Coronation Week more than 2,000 relatives and friends of employees visited the Helsby Works of British Insulated Callender's Cables, Ltd., for the annual "Open Week." Among the visitors were many of the Company's former employees who have now retired. The guests toured the various manufacturing departments and saw the production of power capacitors and the many processes involved in the manufacture of rubber-insulated and thermoplastic-insulated cables of all types.

Automatic Control of Gas Producers

New Scheme with Gas Offtake Temperature Control

THE importance which is nowadays attached to obtaining the optimum performance from a gas producer has emphasised the need for applying automatic control to this process. Such automatic control is particularly desirable in producers subjected to considerable load variations, such as those associated with open-hearth furnaces in unit installations, under which circumstances manual control would be unable to avert large fluctuations in the quality of the gas produced. In any type of installation, however, the application of automatic control will result in considerable improvement over the conditions prevailing with average manual control.



Diagrammatic layout of Kent automatic control scheme for gas producers. Dotted lines indicate control circuit connections and chain-dotted lines measurement connections.

A complete automatic control scheme applied to a gas producer will regulate the input of the three constituents of the process, namely air, steam and coal. Automatic control of gas offtake pressure and blast saturation temperature regulates the first two of these in their respective control circuits, and has been employed in many undertakings as standard producer practice for some time. The advantages which respectively result from the use of these circuits are the ability to meet load demands of the associated plant, and the provision of the optimum proportion of steam in the blast.

Coal Feed Regulation

Automatic regulation of the coal feed, with the ultimate aim of attaining a steady gas quality, can best be effected by employing the related condition of gas temperature as a criterion of such quality, and as the control condition in the control circuit. Although past attempts at control of gas offtake temperature have met with considerable technical problems, these difficulties have been overcome in joint development work carried out by George Kent, Ltd., and the British Coal Utilisation Research Association: a complete gas-producer control scheme is now being offered by George Kent, Ltd.

In this scheme, automatic regulation of the coal feed is carried out by means of a coal feed regulator, actuated by a combined control signal which is based partly on a measurement of producer load and partly on the deviation of gas offtake temperature from its desired value. In addition, the full scheme includes control circuits providing for the control of gas offtake pressure and blast saturation temperature.

The ultimate advantage of this application of automatic control to the coal feed is that a gas of higher and more consistent quality is obtained than could be produced with manual control. This increase in quality is effected by enabling the producer to be operated with a deeper fuel bed, since the danger of tar deposition in the gas mains due to falls in gas temperature is averted. The advantage claimed for the Kent scheme for the automatic control of gas temperature is that a good control can be obtained which, on the one hand, does not interfere with the physical and chemical requirements relating to the fuel bed, and which, on the other, is not itself adversely affected by fuel bed conditions such as the presence of flares.

Typical Control Scheme

The complete control scheme as applied to one type of gas producer, equipped with a steam jet blast injector, is described below. This scheme may be modified to suit other similar types of producer.

Gas Offtake Pressure Control.—The gas pressure is detected in the gas offtake duct and is measured by means of a low-range pressure meter containing a two-term pneumatic controller, whose control signal is fed to a diaphragm-operated control valve situated in the steam main to the blast injector.

Blast Saturation Temperature Control.—The temperature of the blast is detected by means of a mercury-in-steel thermometer situated beneath the blast hood, and is measured by a temperature recorder containing a proportional pneumatic controller, whose control signal is fed to a diaphragm-operated control valve situated in the steam by-pass round the blast injector.

Gas Offtake Temperature Control.—The gas temperature is detected by means of a thermocouple situated in the gas offtake duct, and is measured by a potentiometric temperature recorder containing a three-term pneumatic controller, whose output signal is added to that generated by a load signal transmitter. The latter is a pneumatic unit installed in a steam meter which measures the pressure of the steam at the inlet to the blast injector of the producer. The combined control signal is fed through a differentiating relay to a standard Kent power cylinder, which positions the coal feed regulator, thereby regulating the rate of coal feed to the producer.

How Precious are the Precious Metals?

By John M. West

"Gold and silver having been chosen for the general medium of circulation, they are, by the competition of commerce, distributed in such proportions amongst the different countries of the world as to accommodate themselves to the natural traffic which would take place if no such materials existed, and the trade between countries were purely a trade of barter."—RICARDO.

"The art of our necessities is strange,
That can make vile things precious."
—KING LEAR

A CONSERVATIVE estimate puts the world supply of gold at 100,000 tons, but a much more probable figure would be in the region of several millions—say five million tons—and by far the largest proportion is stored in the vaults and strong-rooms of the world's banks. This precious metal is represented in circulation by bank or treasury notes distributed throughout the community. The values which these notes express are measured in terms of the cost of extraction of the gold, but it is a curious thing that, as the foregoing quotation from Ricardo allows, national and international trade proceeds precisely as though such a material did not exist, the only purpose achieved by fixing the price of the commodity, gold, being the establishment of an absolute value against which the prices of all other commodities can be measured. But such a purpose might be just as arbitrarily achieved by fixing the price of some other commodity or commodities, and, if it is found necessary to store the chosen commodity in vaults (a necessity which I propose to call in question), then at least it need not be a commodity of such potential use to the community as is gold. Let us examine the causes which have led to the present paradoxical situation.

Origins and Growth of the Gold Standard[1]

Gold, practically speaking, is the only metal which is found native in fairly wide distribution. Once discovered, its beauty and ductility, so ably fitted to display pomp and distinction, would have been a constant incentive to the latent skill of primitive man and invite the exercise of his ingenuity. We cannot think of it in its early association with man as being coveted for any other purpose but direct use in the art of the craftsman; nor can we think of this art flourishing unless under the protection of rulers who put some value on industry and order. We can thus conceive that the subsequent habit of concealing, or withholding, the metal may have been due to the fact that in a primitive community, only slightly less savage than its neighbours, frequent lapses from the standard of order which some wiser chief may have established were possible on his decease, life in such times being naturally of somewhat uncertain tenure. The possession of personal ornaments coveted by the unscrupulous would at such times expose the owner to danger, and, consequently, the art of concealing such valuable articles until more favourable times set in would be carefully cultivated. We must, moreover, imagine that ornaments were the first mobile form of personal property, the first opening which men, and more especially women, found for their individual wishes in economic exchange. This would apply especially to ornaments of gold, for their malleability would permit craftsmen to change their form to suit changes of taste or ownership. Furthermore, a tendency to decorate his shrines and to load the images of his gods with those things man deemed imperishable and beautiful would cause a progression of the royal metal from direct use towards the ascription of mysterious attributes.

We can imagine that when man had progressed so far as to produce other metals and turn them to practical use, gold was already securely established in his esteem for purposes for which it has only been challenged by silver. But the perfect refining of silver must have taken him long to master, and when he did finally accomplish this task the result was that this metal was exalted to fulfil always subordinate, though similar, functions to the first of metals.

When the practice of individual exchange had developed so far that large concentrations of people in cities came about, inevitable confusion in providing for their needs must have ensued. The importation of foodstuffs would have become a regular item in the trade of the city, payment being made partly in the uncoined money of the time and partly in industrial wares produced within its own walls: the value of these wares would of course be measured in terms of the current money. In such a manner, and by insensible gradations, the precious metals would assume the character of things conventionally employed to realise wishes of any kind which traders could satisfy. Everyone who tried to get the best value for his money would be helping to keep the values of the precious metals high, and doing his bit to maintain the great army of precious-metal producers throughout the world, men whom civilised society paid to search for and recover the precious metals. Not that these people were useful in the commoner sense of the word but, from long experience, the community had found it essential to its own welfare that numbers of active young men should be so employed, that the production and distribution of all other goods, and the worth of all contracted services, should be measured against the average cost of extracting gold and silver. In modern times, the greatly extended use of credit must bear some definite relation to the vastly increased amount of precious metal required to measure values in present day commerce. The precious metal is still gold because, although the cost of extraction varies slightly from place to place and from time to time, there is no article which maintains a better average stability in the various central markets where its value for conventional use is determined. The gold is, however, no longer in general circulation as

coin (introduced to avoid fraud by alloying and false weighing) but has been withdrawn and replaced by notes of credit, that better control may be had over the currency stocks owned by any one country.

With such a picture in mind, we can see that the reasons for the adoption of gold as a currency metal and for its retention as bullion in the present day are threefold, namely, its mystical value, its chemical inertness and its rarity. That gold has a mystical value even to-day is beyond question: one has only to enter the nearest church to see an altar or reredos laden and inlaid with the metal; one has only to remember the superstition concerning silver which it was necessary to overcome before that metal could be "demonetarised." As for the chemical inertness of gold, it is precisely this quality which now makes the metal so desirable for chemical and industrial use—in curious contrast to the time when it was possible to say that it was this very quality which precluded gold from any other use but the "precious" one of ornament and, later, currency. Gold is becoming increasingly diffuse in its distribution, and it is this which counterbalances improved methods of extraction to keep the average cost of production sensibly constant and at so high a value. The lack of chemical activity exhibited by the metal is no longer of great importance so far as bullion is concerned: an (expensive) corrodable material would do just as well provided that certain precautions were taken at the vaults to exclude corrosive reagents: it could be kept *in vacuo* without too great inconvenience!

If we are to replace gold by some other commodity, we must consider first what use we are to make of the "demonetarised" metal and then what is the most suitable material to take its place, always assuming that it is essential to our economy that we *should* stock bullion of some description.

Properties of Gold and Silver Alloys

Metallurgical theory indicates that both gold and silver can be strengthened without commensurate loss in resistance to corrosion, electrical conductivity and workability. Silver- or gold-rich homogeneous alloys of the solid solution type may be expected to exhibit greater strength and hardness without substantial loss in corrosion resistance but with material loss in conductivity; whilst polyphase alloys should have varying properties according to the relative quantity and distribution of the noble metal within the microstructure. For example, polyphase alloys rich in gold or silver will probably be more subject to corrosion as a result of selective attack on the less noble phase, or of galvanic action between dissimilar phases, but, if the second phase is present in only slight amount and can be precipitated from solid solution, then the conductivity may not be greatly reduced although strength, hardness and abrasion resistance may be substantially improved. We can also expect an improvement in certain base-metal alloys by adding but relatively small amounts of gold or silver, e.g., 0·04% silver will substantially raise the recrystallisation temperature of copper, an expense which is justified by the improvement in applications involving cold work.

In 1937, a Silver Project was instituted by the U.S. National Bureau of Standards, whose purpose was to collate all known data on silver in its industrial applications. The Project was able to report[2] that there is a general tendency for silver to raise the annealing temperature, increase the resistance to corrosion and, in some measure, to improve the hardness of metals. Hardness improvements are accomplished in the case of the soft metals, such as tin, lead, zinc, aluminium, magnesium and copper, by an additive solid solution effect, and in the case of certain alloys such as those of aluminium, the bronzes and brasses, by the precipitation of either a silver-rich phase or a silver compound after suitable heat treatment. The effect on corrosion resistance is found to depend, as one would expect, on the relative position of the base metal in the electrochemical series, those which are comparatively noble (lead, tin, copper) suffering no appreciable loss, and those lower in the series (aluminium and magnesium) often having their corrosion resistance greatly reduced, thus offsetting the advantages gained by increased hardening. Precipitation-hardened alloys are, in general, strengthened as well as hardened and toughened, but there is usually a correspondingly small loss in conductivity and ductility. Silver is also found to impart grain refinement, good bonding properties to welding, brazing and soldering alloys, and, in the case of steels, improvement in machinability; this last effect has been attributed to the low solubility of the metal in iron. Having regard to all these advantages, it is hardly surprising that silver and its alloys have numerous applications in industry, including uses in high- and low-temperature bonding, catalysis in organic syntheses, fungicides for control of plant diseases, photography, medicine and sanitation. These applications are, however, of little account when compared with the much larger-scale applications in the production of bearings, electrical contacts of all description, corrosion-resistant linings for chemical vessels and an improved stainless steel: the addition of less than 1% silver to 18/8 stainless steel increases its resistance to wet corrosion and remarkably improves its workability. A similar quantity added to Armco iron is found to reduce ingot porosity to a minimum. It may be noted here that alloys which are not commercially economic when silver is selling at over £1 per lb. may be justifiable at a lower price. What is more, a larger silver content (greater than 5% say) in a given alloy may be considered in more favourable circumstances.

Although gold has neither the remarkably high conductivity nor the bactericidal and photographic uses of silver and its salts, it has considerably greater corrosion resistance, its electrode potential being more than 0·6 volts higher. This metal, then, is pre-eminently suited to replace silver in applications involving protection against atmospheric and chemical attack. Because also of its remarkable chemical similarity—as may be predicted from its electronic configuration—such replacement could indeed be far more general. In addition, it is more than likely that, once gold has been freed from monetary entanglements and been submitted to intensive research and development, as was silver when that metal was demonetarised, many hitherto unsuspected uses will be found for it in industrial fields and, more important, improved methods of extraction will be at a premium and should serve to keep the price of gold low once the bullion stocks have been used up.

Titanium Standard Suggested

If, in view of the foregoing, it is thought desirable to release gold bullion stocks for industrial purposes, we

must next decide what material is best fitted to replace our emancipated metal. The chief consideration is, of course, that the new metal must be fairly expensive—if possible as expensive or more so than gold—and, if similar arguments are not subsequently to apply to the material, it must be both abundant and available for industrial use in an impure form. With these considerations in mind we should therefore examine the prices of the pure metals. We find[4] that titanium at 99·7% purity is worth approximately £80 per lb. compared with the (99·9% gold) bullion price of £200 per lb., whereas all the other metals, except platinum, fall far short of this figure (99·5% lithium, £12 ; 99·99% cobalt, £7 ; and 99·99% iron, £6/10 per lb. respectively). Titanium, then, appears to be our best choice : there is no doubt of its abundance (there are estimated to be 10^{17} tons in the earth's crust) and, if the necessary trouble were taken, no doubt the price could be raised sufficiently by increasing the purity to (say) 99·99%.

The extraction and refining of titanium is at present being very actively studied all over the world because of its useful properties. Its combination of relatively low density (4·5), high strength (expected to equal that of steel when happily alloyed) and good corrosion resistance, being thought to promise a material which will bridge the gap between the light metals and iron and steel. Titanium occurs as *ilmenite* ($FeTiO_3$) in massive deposits, which can often be worked by open-cast methods, and as *rutile* (TiO_2) which occurs in beach deposits. The metal is chiefly produced in sponge form by the Kroll process, where the crushed ore, after suitable flotation procedure, is chlorinated and the purified halide is then reacted with magnesium at red heat in an inert atmosphere. The sponge-titanium, although relatively impure, is particularly suited to powder metallurgical techniques, but further refinement is difficult because, at temperatures above 400° C. or so, the metal is particularly prone to absorb every conceivable impurity. It is this factor which results in the high price of 99·7% titanium.

Other Standards

Before considering the suitability of titanium further, it is necessary here to state that there is an argument which condemns the use of only a *single* commodity against which to measure prices and which amounts effectively to an argument against the storing of bullion. Gustav Cassel[3] maintains that far greater economic stability could be achieved by fixing the prices of *several* arbitrarily-chosen commodities instead of one, gold. One can understand why he should have been so passionate in advocating this theory when he did, in view of the economic chaos which, but four years previously, had been caused by excessive hoarding of gold, with the attendant scarcity of currency metal. This argument is to some extent nullified if the currency metal is in such abundance that all that is required to increase the quantity available (to correspond to increased commercial activity) is the further refining of the available metal to a sufficient degree of purity.

There is nothing new in the idea of using some other currency metal than gold or silver. Between the fifth and third centuries B.C., the chalcopyrite deposits at Agordo and Massa Maritima led Rome to adopt a Copper Standard, despite the later cheapness of that metal. There is evidence that the "precious" metals were used solely for ornamental or dedicatory purposes, and it was not until the Roman Empire had embraced the economies of many nations that her accumulated stocks of silver and gold led to the adoption of silver as currency. At about the same time, in the fourth century, Lycurgus evolved a rigid way of life for Sparta and, believing that thereby he could prevent the absorption of Sparta into international trade, he introduced *iron* money, iron being at that time about as costly as copper. No doubt he imagined that such would have the further advantage of making readily available a material which could be converted into weapons in time of war. The experiment was not successful since the closed community came in time to covet money excessively, because it was unable to maintain a balanced view in the absence of intercourse with other nations, and this was a state of affairs which Lycurgus had desired expressly to prevent.

In this essay we have advocated a switch from the Gold Standard to a Pure-Titanium Standard. This should release gold for industrial purposes and yet leave titanium free for further industrial development. Naturally, the change would have to be brought about by international agreement and of course considerable fluctuation in world prices must occur during the transition period. We should expect, however, that the entire economic structure would be compelled finally to adjust itself to the new monetary system and economic equilibrium thereby be established. Then, and only then, would the first of metals be freed from its "precious" fetters.

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Safety Week at Kodak

KODAK, LTD., are proud not only of the fine photographic equipment which they produce but also of the excellent conditions under which they produce it. This was demonstrated recently at a most successful and comprehensive Safety Exhibition which was held at the Kodak Factory, Harrow.

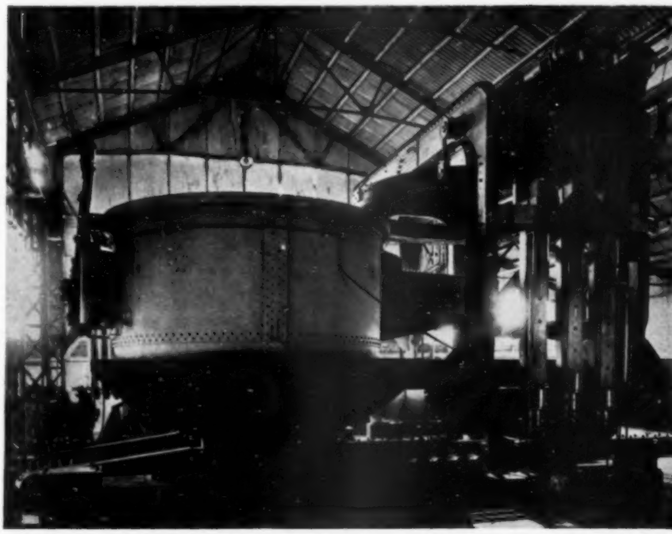
The purpose of the large number of exhibits was to bring home to employees, their families and friends the ever-present danger of accidents due to carelessness or ignorance. The story was presented in an instructive, lively and frequently humorous manner. The industrial exhibits covered every aspect of factory life, the newest type of safety lifts and automatic doors, correct clothing, tools and equipment, fire precautions and first aid, and even demonstrated the right and wrong way to lift a wheelbarrow.

On the domestic side, dramatic exhibits showed the fatal results of faulty electrical appliances in bathrooms, and the dangers to both children and adults of unguarded fires. Other more general exhibits which drew the crowds included the car driving test, the reaction-test and one item that demonstrated in an amusing manner the folly of lighting matches in gas-filled rooms or near petrol tanks. The majority of the stands and exhibits were made on the premises by Kodak workers. Each evening throughout the week continuous film shows illustrated safety measures in the factory, in the home and in the street. The exhibition was attended by about 8,000 people, including organised parties from other factories and from schools.

Hydraulic Arc Furnace Electrode Control

THE critical portion of an arc melting furnace upon which general running efficiency and economic production depend lies in the means whereby the movements of the electrodes are controlled during the melt. The object of controlling the electrodes is to maintain the arc current as far as possible constant between the electrode and the material with which the furnace is charged. As the arc is lengthened, so the current decreases and it is upon this basis that automatic electrode control devices have been designed. To avoid the inconvenience and inaccuracies previously associated with manual electrode operation, study has been made of regulation by means of automatic devices which, under the control of the current, act immediately upon the electrode operating mechanism.

Automatic regulating devices of various types have been supplied to arc furnaces, the majority of them being based on electro-mechanical principles and operated by motors connected mechanically to the electrode operating mechanism. The inferior results obtained mechanically by these electro-magnetic regulators, which are normally of the rotary amplifier type, are due mainly to the inertia of the relatively heavy masses of the motor armatures, and the motions between the various devices of the complicated system. This inertia factor is a great disadvantage, especially during the actual melting period, when the charge is liable to fall against the electrode, causing a short-circuit, and when the molten metal is running away from the electrode, under both of which conditions rapid movement of the electrodes takes place. The high speeds and rapid acceleration required are best obtained by means of a hydraulic control system.


Bridge type furnace with lid raised and furnace body in position for charging.

The firm of Ing. Leone Tagliaferri of Milan have specialised in the design and construction of arc melting and smelting furnaces since the early twenties, and in 1930 a hydraulic electrode control regulator was evolved which has since been developed to a stage where it is claimed to be superior to other methods at present in use. In this method, adjustment of the electrodes is effected by means of hydraulic cylinders applied directly to the electrode supports and operated by water supplied under pressure by pumps.

At this juncture, it may be pointed out that the Tagliaferri method of hydraulic furnace control constitutes a common system providing motive power for tilting the furnace body, lifting and swinging aside the roof (if the unit is loaded in this manner), raising the door, and of course, operating the electrodes. Normally a pair of electric pumps are fitted (one spare to ensure continuous operation) in the sump supplying the water to the accumulator tank, to which is also connected a compressed air bottle. The primary function of the compressed air feed is to damp the pressure oscillations which may occur during operation, and to permit lifting the electrodes in the event of failure in the electric supply to the feed pumps. Water is fed from the accumulator to the various distributing points of the system, including the electrode regulator which comprises a hydraulic distributor with three branches, a manual operating device and an

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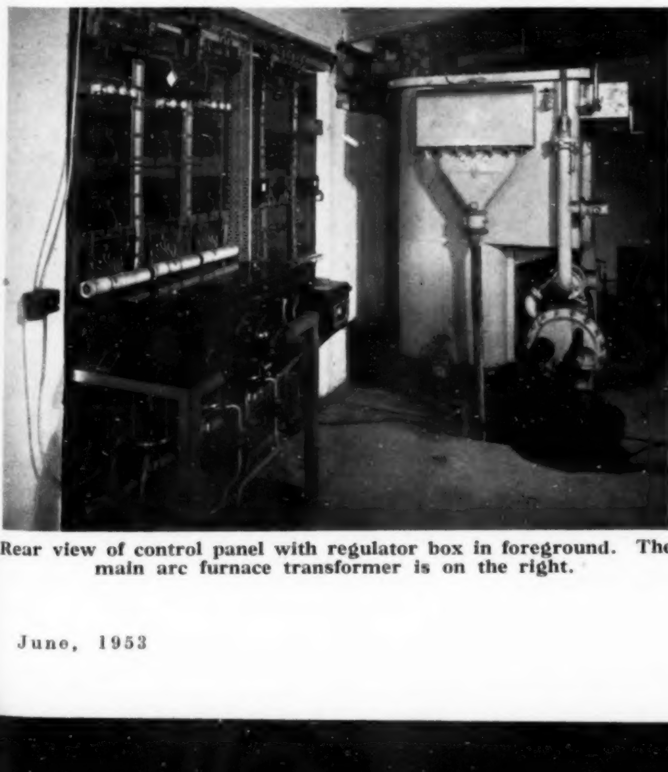
Rear view of control panel with regulator box in foreground. The main arc furnace transformer is on the right.

Metal Casting Methods

III—Continuous Casting

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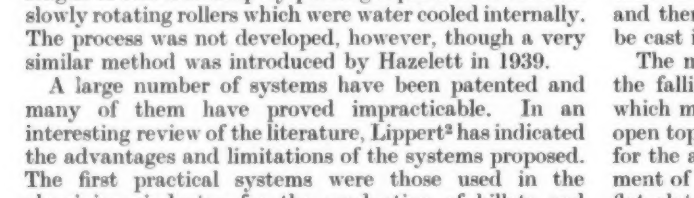
The continuous casting process approaches the ideal, its cardinal virtue lying in its ability to promote directional solidification, with the resultant improvement in billet quality. The method is widely used for aluminium alloys, and is gaining ground in the copper alloy field, whilst considerable development work has taken place in the ferrous field.

THE ill effects of shrinkage in cast metals and alloys were recognised many years ago, and casting methods of a continuous type have been proposed by many workers. Continuous casting methods involve the use of controlled pouring and solidification rates, and may be adapted to the production of simple billets (or ingots) and more complicated shapes such as sections. It was early realised that much of the cost involved in mechanical working operations could be eliminated if an efficient continuous casting system could be developed, and metallurgical literature contains many references to such systems, a patent being granted to Laing for the production of lead pipe by continuous methods as long ago as 1843. In 1857, Bessemer[1] was able to produce a length of soft iron strip by pouring liquid metal between slowly rotating rollers which were water cooled internally. The process was not developed, however, though a very similar method was introduced by Hazelett in 1939.

A large number of systems have been patented and many of them have proved impracticable. In an interesting review of the literature, Lippert[2] has indicated the advantages and limitations of the systems proposed. The first practical systems were those used in the aluminium industry for the production of billets and slabs in long lengths for extrusion, rolling and forging. For zinc, lead and tin, the process offers no difficulties, and the metallurgical problems involved in the continuous casting of copper alloys have been satisfactorily solved. The rate of pouring is much higher than with aluminium alloys, and those alloys containing zinc or aluminium must be cast in conditions which shield the metal from both oxidation and undue turbulence. Considerable development work has been carried out on the application of continuous casting to steel, and cast iron has been cast continuously on a limited scale.



Courtesy of The Journal of the Iron and Steel Institute.

Continuous strip casting machine (after Bessemer).

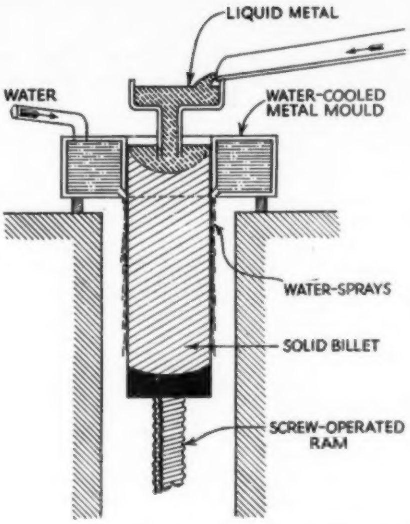
Stationary Mould Method

The term continuous casting is frequently misapplied in that it is used to refer to semi-continuous casting, in which long, but definite, lengths of billet are produced. In true continuous casting, lengths are cut off the moving billet at the same time as further metal is being poured, and there is no limit to the amount of metal that may be cast in one continuous operation.

The most commonly used casting system is probably the falling table method. In this, the mould, or die, which may be circular or rectangular in cross section, is open top and bottom, and may be of hollow construction for the application of water cooling. At the commencement of pouring, the bottom of the mould is closed by a flat plate or table which, as solidification takes place, is lowered from the mould, so that subsequently the molten metal is supported by that which has solidified previously.

The function of the mould, apart from giving the billet shape, is to abstract from the metal sufficient heat to ensure that a wall of solidified metal, capable of withstanding the hydrostatic pressure of the liquid in the middle and the stresses resulting from subsequent cooling, has formed by the time the billet emerges from the bottom of the mould. One of the main objects of the method—directional solidification from the bottom—will be defeated, however, if too much heat is abstracted by the mould. The main cooling is obtained by spraying the billet with water below the mould, or by lowering the billet into water. A mould length of 3–6 in. has been found suitable for the continuous casting of many metals and there is nothing to be gained by increasing it unless the alloy being cast is sensitive to cracking. Longer moulds tend to result in increased friction between the mould and the billet. Single moulds or groups of moulds may be operated at the same time, and Roth[3] quotes six–8 in., four–12 in., or three–16 in. diameter ingots as practicable in aluminium alloy production.

The means of withdrawing the billet from



*Courtesy of The Aluminium Development Association**

Semi-continuous casting of billets.

the mould may be mechanically or hydraulically-operated rising and falling tables, or rollers between which the billet passes. The rollers are usually grooved to assist gripping and to help to support the weight of the billet. For true continuous casting, the use of a falling table is not possible, and rollers or some similar device are essential, a " flying saw " being used to cut off lengths of billet as casting proceeds.

Williams has developed an improved falling table system which can be applied to steel casting. In this case a thin-walled water-cooled copper mould is used and the rate of heat abstraction is relatively great. The inside may still be molten, however, and to prevent bulging, the cast billet is passed through a series of sizing rolls as it emerges from the base of the mould assembly. Additional water cooling is then applied.

Advantages of Continuous Casting

The continuous casting process approaches the ideal casting technique, its cardinal virtue lying in its ability to develop vertical rather than lateral heat extraction. In this way there is little possibility of piping and the casting conditions can be adjusted so that the solid/liquid interface is in the form of a shallow saucer rather than a deep cone : in some cases, it may even approach the ideal of a flat surface. The thermal conditions existing in water cooled moulds, and the application of these principles to continuous casting, have been thoroughly reviewed by Scheuer[4], who has shown the importance which must be attached to the maintenance of this flat solidification front. He points out that when the cooling in the mould proper is adjusted to a degree just sufficient to form a thin vertical solid crust on the mould walls, and the lower part is cooled as severely as the metal can stand, the depth of the liquid metal cup is rarely more than the diameter of the billet. The limitation on the amount of cooling is set by the severe gradients in the solidification zone, which in certain alloys tends to produce longitudinal cracks (hot tears). With increase in pouring rate, the depth of the cup increases. Two further defects connected with radial heat flow can be avoided by the attainment of a flat solidification front : they are inverse segregation and shrinkage stresses.

The fact that the molten surface of the billet is more or less stationary means that, during the whole operation of pouring, the metal can be introduced quietly with the minimum of turbulence and oxidation, so that trapped oxide, slag and gases can be avoided. Because of the short path from the ladle to the mould, a low casting temperature can be employed, which avoids the danger of gassing the melt and facilitates rapid solidification. The microstructure of continuously cast aluminium alloy billets shows a finer distribution of constituents and an absence of micro-porosity, when compared with the same alloy cast in a cast-iron mould.

Apart from, or in addition to, the metallurgical benefits by way of billets with improved structures, the continuous casting process is used to obtain the advantages which accrue from rapid production. It is a convenient and economical process, and the ease of control of the pouring speed and pouriug temperature, on which the properties of the finished casting depend, enables a high degree of uniformity to be attained.

The surface of continuously cast billets may be variable, and is not so good as that of Durville cast material. For this reason, it may be necessary to machine the billets before forging, extrusion or rolling, but the defects are confined entirely to the surface and are not subcutaneous. Cast material which is drawn through rolls may be better than that produced by the falling table method.

The Development of Continuous Casting

An interesting account of the development of the continuous casting process has been given by Scheuer,[4] in which he mentions some of the more valuable solutions to the problems confronting those attempting to develop an ideal casting process. In order to reduce turbulence in pouring, tilting the mould almost to the horizontal at the commencement of pouring was tried, the Durville process being a refinement of this method. Fairly recent processes involve the use of a spiral channel wound round a heated central column, or a funnel with a narrow vertical tube attached. These are lowered into

Courtesy of Northern Aluminium Co. Ltd.

Pouring molten aluminium into the water cooled mould in semi-continuous casting.

* *Prepared for A.D.A. Information Bulletin No. 1.*

the mould from the top and discharge immediately on the liquid level.

In the Züblin process,[5] a rectangular mould with a solid bottom and only three vertical sides is used. The fourth side is closed by cast iron blocks in the form of a caterpillar chain. Only one block is in position when pouring commences, the metal being discharged from a short pouring channel, which also allows of the use of a low casting temperature. As pouring proceeds the mould is lowered and another caterpillar block is aligned above the first one. This method was used in the large scale production of high strength aluminium alloys in Germany before the war.

Hermann[6] has reviewed the development of caterpillar chain type machines, which include also those which consist of series of split moulds carried on two chains and coming together at the top and parting at the bottom, releasing the billet formed during the interval. Both these methods are good in that they provide a stationary or near stationary condition of the solidification zone. They do not, however, provide a flat solidification front. Attempts to attain this goal include the pouring of the metal as quickly as possible into a thin-walled tapered steel mould which does not cool the metal below the freezing point. When the mould is full, and slag and dross have risen, the mould is cooled from the bottom by lowering into water, or by letting water rise in a tank round it. One of the drawbacks to this method is that the cooling is limited as soon as the solid crust has formed and an air-gap appears between the mould and the billet. In the continuous casting process, of course, cooling is applied directly to the billet itself.

Strip Casting

Bessemer's apparatus was designed for the production of strip from liquid metal with considerably less rolling than the normal procedure involves. Many technical difficulties arose and the process was not developed. The roller type of continuous casting process has, however, been brought to the production stage by Hazelett.[7] There are the same advantages as with the sleeve mould method as regards feeding right to the top of the metal sump, making possible low pouring turbulence and low pouring temperature. The intense cooling is in this case maintained in the lower parts of the solidification zone by the plastic compression of the billets between the rollers, which eliminates the air gap. Furthermore, the V-shaped arrangement of the cooling surfaces helps considerably in flattening the solidification cup.

The Hazelett process suffered much alteration before the present method was adopted for the production of copper alloy and stainless steel strip. Material cast in this way is said to have a microstructure similar to that observed in hot-worked material. Appreciable variation in grain size is seen owing to temperature changes, and to variations in roll settings.

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Hydraulic Arc Furnace Electrode Control

continued from page 291

automatic regulator with electro-magnetic control and oil servo-motor.

Automatic regulation is effected in the following way. A differential piston, in the head of which are several ducts, slides inside a bronze cylinder. A rod, attached to the piston, is fixed to a stirrup plate which, in its turn, is integral with the piston of the distributor. A valve, situated just above the differential piston, has longitudinal grooves which in a certain position correspond with one of the little orifices in the head of the differential piston. In this position, oil from a pump flows straight through the chamber back to the sump, while, in the absence of any pressure build-up, the piston is retained in the bottom position by means of a helical spring. The position of the valve in relation to the differential piston is determined by the variations of the magnetic flux in the movable core of an electro-magnet, since the valve itself is integral with the core. The flux is proportional, within certain limits, to the variation of the intensity of the current circulating between the transformer and the furnace.

To sum up, the electrodes are attached to pistons, the movements of which are caused by water under pressure, the flow being governed by a valve linked to a piston which is operated by oil pressure on one side and an opposing spring on the other; the variations in the electrode current are reflected in a movable magnetic core attached by a rod to a piston controlling the oil flow. It is evident that in such a system the inertia is negligible.

The regulator is normally adjusted so that it will come into action within 1/7th of a second, with a variation of $\pm 1\%$ of the pre-arranged current value, which can be varied from $\frac{1}{4}$ to full load amps. by means of an adjustable resistance. Another advantage of this system lies in the simplicity of construction and the fact that, apart from the piston valves, no piece of the unit is subjected to wear. All the electro-magnetic and hydraulic servo-motor system is completely enclosed in a hermetically sealed oil bath. During the slagging operation, the electrodes can be withdrawn simultaneously from the bath by 4–6 inches. On re-setting the lever, the electrodes return to strike the arc.

There are several ways of loading arc furnaces, the three principal types available in the Tagliaferri range are (1) rising and swing aside roof; (2) the 'bridge' type in which the furnace body is moved out from under the roof, which is carried by an overhead steel framework when raised; and (3) the fixed roof type in which loading is carried out through a rear door.

Furnaces incorporating the Tagliaferri electrode regulator system represent an installed capacity of over 750,000kVA, and several units have been erected in the United Kingdom since the war by G.W.B. Electric Furnaces Limited, who are the sole licensees.

New A.P.V. Factory and Foundries

Expansion Needs Met by Move to Crawley

THE A.P.V. Co., Ltd., is one of the largest manufacturers of plant in stainless steel, aluminium and copper for the dairy, brewery, food, chemical, oil and varnish, beverage and pharmaceutical industries. It was founded at Wandsworth, London, in 1910, as The Aluminium Plant and Vessel Co., Ltd., by Dr. Richard Seligman, who held a patent for the autogenous welding of aluminium in conjunction with a Swiss firm. As the name implies, the firm was set up for the fabrication of industrial tanks and vessels in aluminium, and it has since taken a leading part in developing the welding of corrosion-resistant metals.

In 1922, Dr. Seligman invented the plate type heat exchanger, and this device, known as the Paraflow, has become virtually the standard equipment in dairies for the pasteurisation and cooling of milk; in breweries for wort cooling, beer pasteurisation and other duties; and in many other industries for the pasteurisation, heating and cooling of potable liquids. This development is now A.P.V's principal product, and since its introduction the Company's activities have followed a process engineering trend, until to-day it designs and manufactures complete installations for the industries it serves.

The rapid growth of A.P.V. in recent years resulted in an unwanted dispersal of its production facilities among four factories at Point Pleasant and Garratt Lane, Wandsworth, at White City, and at Slough, Bucks. The restrictions on building and the lack of adequate space eventually decided the company to move all its production facilities and head office to an entirely new factory and foundry to be built in the New Town at Crawley, Sussex. The handicaps of improvisation could then be removed and every advantage taken of the most up-to-date ideas in factory planning and equipment.

This move is being carried out in two stages; the first of these is now completed, and includes the fitting, machine, press and polishing shops, and also the foundries which are under the control of the subsidiary company, A.P.V.-Paramount Ltd. The head office and the coppersmith shops remain at Wandsworth and will constitute the second stage of the move soon to be commenced.

One thousand four hundred people are involved, and houses are being provided in the Crawley New Town for all who require them. Five hundred people are already working in the new factory and most of these are housed in the New Town. The move has thus considerable social implications as it involves a radical change in the way of life of A.P.V. employees. From being widely dispersed in and around London, they are now concentrated in a single, compact community. A noticeable feature of the move has been the loyalty exhibited by all members of the company. The overwhelming majority of those up to the present affected having moved to Crawley, and the loss of skilled personnel has been insignificant.

The fitting shop.

The New Factory

The factory and foundries cover an area of 200,000 sq. ft. on a 17-acre site at Manor Royal, and are by far the largest works in the Crawley New Town. Entirely separate blocks, each with their own administrative offices, are provided for the factory and foundries, the former covering 128,800 sq. ft. It consists of five 475-ft. bays, with parts of three further bays which will be extended later; the frontage is taken up by the works offices.

The layout of the factory provides for a general flow of production from the front to the rear, and the stores, which take up the front ends of the bays, are served by the large goods entrance that forms the most noticeable feature of the frontage. The machine, press and polishing shops stretch across all bays, while the fitting shop occupies most of the large 60-ft. bay and one other.

Travelling cranes serve the bays, from the stores in front to the doors in the rear for despatch of the finished products, whilst a broad gangway across the bays provides for transport by trucks from one bay to another. Considerable attention has been given to material handling, and fork-lift trucks are widely employed with box and other pallets. Materials and small parts, in storage and in course of production, remain at all times in these pallets, right up to final assembly.

The machine tools are of the latest types and wide use is made of automatics and semi-automatics for the production of stainless-steel pipe fittings and other repetition parts. A number of ingenious machines and methods are employed, having been designed by the company's engineers for its special requirements.

The factory building is of welded steel portal-framed construction giving free headroom, with complete absence of cross members, The most noticeable feature of the factory on first entering it is the bright colouring,

The press shop.

it being an outstanding example of the application of the British Standard Colours for Factories. The steelwork is in blue, while cranes and all moving parts are in red; machinery is in green and all pipes and mains are coloured according to their purpose. The roof is of aluminium and glass which, with the blue steelwork, provides a very cheerful and light effect.

The New Foundries

In 1912 an aluminium foundry was established, which soon built up an extensive business in producing castings for other firms, and it quickly grew to become an important part of the company. The increasing trend towards the use of stainless steel made it necessary for the company to find a source of supply of castings in this material. At the time, the technical difficulties encountered in casting stainless steel were such that only a few foundries were in a position to offer a consistent and reliable supply. One of these was Paramount Alloys, Ltd., of Slough, a company formed in 1945 for the special purpose of producing stainless steel castings. In 1947, A.P.V. purchased Paramount Alloys outright, and ran it as a subsidiary company. Its name was changed in June, 1952, to A.P.V.–Paramount, Ltd., and at the beginning of this year, when the new foundries at Crawley were ready to start up, the A.P.V. aluminium- and copper-base alloy foundries were incorporated in this company, and it now operates as an independent subsidiary of A.P.V., controlling all the foundries.

The new foundry at Crawley, which is designed to provide a complete castings service to its customers in stainless steel, aluminium- and copper-based alloys, is divided into two autonomous units, one for ferrous castings, the other for non-ferrous. While they share a common service for cores and patterns, they are equipped with their own separate furnace lines, sand plant and fettling arrangements.

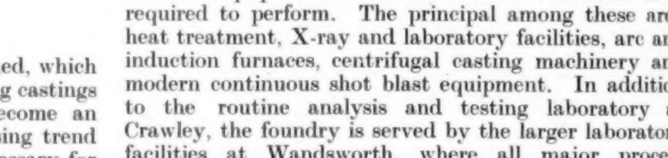
The foundry is not designed for mass production of any single line of castings. On the contrary, it is laid out to achieve maximum flexibility, and can, therefore, manufacture castings of a wide variety of size, shape and quantity, in any of the three main groups of alloys mentioned above. Since all services are distributed to many points in the foundry and moulding sand can also be easily distributed, the layout of the foundry can be altered without difficulty to suit different types of production.

Special attention has been paid to planning the layout of the foundry in order to minimise materials handling, and to effect smooth flow of castings from their origin to the point of despatch. It is a fact that, in the average foundry, for every ton of castings despatched, 100 to 200 tons of material have to be lifted and moved. Any economies that can be made in materials handling and travel are, therefore, of prime importance.

In the flow of castings from origin to despatch at no point do lines of flow cross, and the feeding of patterns, cores, moulding boxes and sand to the moulder all follow pre-arranged lines.

The planners of the foundry were able to visit many modern foundries, both in Europe and the U.S.A., and the Crawley foundry, therefore, contains the most modern equipment available for the functions it is required to perform. The principal among these are: heat treatment, X-ray and laboratory facilities, arc and induction furnaces, centrifugal casting machinery and modern continuous shot blast equipment. In addition to the routine analysis and testing laboratory at Crawley, the foundry is served by the larger laboratory facilities at Wandsworth, where all major process research is carried out.

Perhaps the most striking feature of the new foundry is that in respect of working conditions it does not seem like a foundry at all. It has always been a matter of



Exterior view of the foundry.

great concern to the foundry industry that the recruitment of young labour has been falling off. The classical foundry with its earth floor, smoke-laden atmosphere and terrifying aspect has been the main reason for this undesirable decline in recruitment. In the new foundry at Crawley, special attention has therefore been paid to working conditions and amenities. The Garratt Report on minimum amenities for foundry workers has been followed in every aspect of the foundry, and in some cases has been bettered.

The building consists of two 60-ft. main bays, 250 ft. long, one being the stainless steel foundry and the other the non-ferrous foundry. A 20-ft. middle bay houses the furnaces and their auxiliary equipment, including the generators. The offices, which are on two floors at the front of the foundry block, accommodate the sales, production, methods, technical and financial staffs.

The non-ferrous foundry.

The new pattern shop, which is housed in the same two-storey building, is being expanded, and will embody all the modern machinery required for efficient and accurate pattern production.

Methodical pattern storage is one of the major problems in a foundry, and at Crawley over 1,000 patterns and core boxes are issued and returned to stores each week. They are stored in specially designed and numbered racks for quick and easy reference, different metals being distinguished by a colour code. Patterns are also segregated according to the method of production to be employed, separate racks being provided for each type of moulding machine and for hand moulding. The issue of sample and production patterns is controlled to meet the requirements of the production office.

Sand Plant and Core Shop

Sand is the most important item in any foundry since the quality of the sand, more than anything else, determines the quality of the casting. The August sand treatment and distribution plant provides one of the most important features of the new foundry. It consists of three separate units—one for the non-ferrous foundry, one for the core shop and one for the stainless steel foundry—and is under the supervision of one chargehand and four operators. This function in an unmodernised foundry requires a heavy labour force and cannot be carried out with the same degree of control of composition of mixture as is possible in this new plant. Sand is stored in large hoppers, mixed and milled together in the twin August mills; it is tested for moisture strength and permeability before being distributed along the overhead conveyor belts into the hoppers which feed the moulding machines.

The control panels regulate the operation of both the underground return conveyors, all the lifting hoppers and the distribution conveyors. It is provided with an interlock system which automatically stops all motors on the circuit should one motor cease to operate. The sand plant as a whole is capable of handling 170 tons of sand in circuit, and due to the sieving and cleaning operations involved, enables the minimum of sand to be rejected.

The non-ferrous sand treatment plant.

The core sand unit processes various synthetic sands which are pre-dried in a rotary gas-fired sand drying machine. The sand is then mixed with oil or molasses binding constituents and issued to the core-making benches.

The stainless steel sand plant, which distributes a mixture of silica sand, bentonite and other constituents, is similar in function to the non-ferrous sand plant.

Cores are normally prepared the day before their requirement by the moulding shops, and are stacked in racks. They are made either on a core-blowing machine or by hand and are prepared in special sand which enables them, when thoroughly

The stainless steel foundry.

dried and baked, to withstand considerable stresses. The layout of the core shop is planned to give high production with minimum movement by the coremakers. A belt feeds the cores into one of the core stoves.

The foundry is equipped with a continuous core drying stove for the smaller cores, and two large batch drying stoves for larger cores. In the continuous stove the tray carrying the cores makes a complete circuit at high temperature lasting two hours. Cores are extracted from the far side of the stove for feeding to the core stacking area. In the batch stoves, cores can be dried overnight for use on the following day.

Non-Ferrous Foundry

In the non-ferrous machine moulding section, the most modern moulding machines available are devoted to the continuous production of non-ferrous castings. The power and accuracy of these machines make them capable of producing castings in considerable quantities at low cost. Machines are operated by semi-skilled labour and moulding sand is fed from a continuous overhead conveyor. The B.T.5 and A.T.2 rollover machines are specially suitable for deep draw work, whereas the smaller machines are suited for the high speed production of small size castings. Moulds from the machines are closed on the roller conveyor prior to pouring in of the metal. As soon as the castings are sufficiently cool, they are knocked out over the knock out grids at the far end of the roller conveyors. The moulding sand falls through the grids on to rotating tables, is ploughed off on to a continuous underground return conveyor, which feeds it back to the sand treatment plant. The casting is then taken by pallet to the core knock out and checking area. Any castings rejected at this point are referred back to the foreman in charge, for decision as to whether the defects are attributable to errors in moulding. All castings in this category have to be replaced by the moulders without payment.

Small numbers of castings, and complicated castings in which quality and accuracy of workmanship are of paramount importance, are largely made in the floor moulding area, where skilled moulders are available.

Melting facilities for aluminium and bronze consist of seven Morgan oil-fired furnaces, which have an output of about 4 tons of molten metal per day. Fuel oil for these furnaces is stored overhead and is preheated and pumped to the oil nozzles; low pressure air is also piped to the fuel nozzles. All pouring pots are preheated in underground pot preheaters, in order to preserve the temperature of the molten metal between the furnace and the mould.

Before the casting can be considered as completed, sand slag and other adhesions to the raw casting must be removed, together with all extraneous metal. A shot-blast chamber is provided for use where required, and in the fettling shop an array of equipment is arranged in a logical order. Cutting-off is carried out by band-saws and abrasive wheels, whilst trimming is effected by high-power high-speed grinding wheels, and by filing.

After fettling, all castings are rigidly examined by the inspection department for quality and, where required, pressure tightness. The Chief Inspector is directly responsible to the Board and is, therefore, in a position to enforce upon the production management the standards of accuracy, finish and quality laid down by the Board. He is also officially approved by the Aircraft Inspection Department as their local representative in the foundry.

Stainless Steel Foundry

The stainless steel moulding shop consists of machine and floor moulding sections employing semi-skilled and skilled moulders, respectively. Stainless steel moulding differs from aluminium moulding in that harder ramming is needed to enable the mould to stand up to the stresses involved in stainless steel casting. In other respects stainless steel moulding facilities are similar to those on the non-ferrous side.

The centrifugal casting method is suitable for all annular components in stainless steel and other metals, and produces a casting of high quality, notably free from the normal casting defects. Two spinning machines for this process are housed in a sunken pit.

The stainless steel foundry is equipped with four furnace units. The Metalelectric arc furnace is capable of melting 1½ tons of metal every 90 minutes and is equipped with oxygen blowing apparatus, used for the control of carbon content. It is an extremely flexible and economical unit. The other three units are Efco high frequency furnaces of 10 cwt., 5 cwt. and 2 cwt. capacities. Each has two furnace body units fed by the same power equipment, so as to enable relining of the body when necessary without interrupting production. The induction furnaces are capable of producing melts of extreme accuracy and purity. Melting temperature, which is of supreme importance in the control of quality, is measured by thermocouple remote recording pyrometers. The combined stainless steel furnace capacity enables the foundry to produce stainless steel castings up to a maximum finished weight of 2 tons.

The generator house, which is on two floors, contains all the power equipment for the high frequency induction furnaces and the arc furnace. The three B.T.H. rotary convertors are capable of an output of 1,000 kW.

In the metal store, all alloying components are mixed in prescribed proportions and fed out to the furnace lines. Runners and risers, which are marked according to an alloy code, are also returned to the metal store for re-issue to the furnace lines.

For cleaning there is a Wheelabrator, which is a continuous shot blasting machine capable of cleaning ½ ton of castings per hour; it is equipped with automatic feed and cleaning devices. Due to its work hardening characteristics, stainless steel needs fettling machinery of considerably higher power than do the non-ferrous metals, and the stainless steel fettling shop is equipped with, among other things, an American Do-All high power continuous saw. Runners and risers of large diameter or section are removed by a flame cut-off operating on the iron-powder principle. After cleaning and fettling the castings are submitted to careful inspection.

Two Incandescent Heat furnaces are available for the heat treatment of stainless steel castings, the annealing temperature normally used being of the order of 1,050° C.

Testing and Control

The process control laboratory is devoted entirely to the supervision and testing of castings. In the laboratory is to be found a Denison 50-ton tensile testing machine, equipment for analytical work, and other normal metallurgical testing equipment. Metallurgical development work is carried on only in the central laboratories at Wandsworth.

Reference has already been made of the fact that equipment is available for the X-ray examination of castings. The 300 kV. plant is capable of handling castings in stainless steel, aluminium, and gunmetal, and has a capacity up to 3 in. Supplementing this equipment for the revelation of porosity, cavities and inclusions, there is a set of gamma-ray radioactive isotope equipment.

Coronation Honours List

continued from page 276

B.E.M.

T. E. ALLEN, Working Burner and Machine Caulker, Vickers-Armstrongs, Ltd.

A. BALL, Electrical Section Leader, Saunders-Roe, Ltd.

W. H. BROWN, Foreman Toolmaker, Ernest Stevens, Ltd.

A. BURDEN, Chargehand, Sigmund Pumps, Ltd.

H. CATLOW, Chief Loom Inspector, British Northrop Loom Company, Ltd.

MISS HANNAH DAVIES, Forewoman, Simmonds Aerocessories, Ltd.

E. DEAN, lately Tool Room Miller, Renold & Coventry Chain Company, Ltd.

W. D. DENHOLM, Principal Smith, N. Hingley & Sons, Ltd.

C. A. DOWNES, Chief Inspector, Bristol Tramways and Carriage Company, Ltd.

J. FULTON, Head Foreman Plumber, Harland & Wolff, Ltd., London.

R. GILBERT, Foreman, Holman Brothers, Ltd.

H. GOODSON, Head Foreman Boilersmith, United Steel Structural Company, Ltd.

T. C. HACKETT, Foreman Bricklayer, Phillips Cycles, Ltd.

F. P. HUDSON, Maintenance Fitter, British Industrial Solvents, Ltd.

J. HUSBANDS, Electrical Fitter, Electric Construction Company.

J. S. JEAL, Centre Lathe Turner, Dewrance and Company, Ltd.

H. R. JOHNSON, Engineering and Maintenance Foreman, Whessoe, Ltd.

D. JONES, Leading Hand, Zinc Distillation Plant, National Smelting Company, Ltd.

W. H. JONES, Foreman, Hemp Small Splicing Department, Wrights' Ropes, Ltd.

L. LEACH, Process Foreman, Magnesium Elektron, Ltd.

P. J. T. MACAULEY, Leading Draughtsman, Cammell Laird and Company.

A. MCCULLOCH, Chargehand, Drysdale and Company, Ltd.

J. MURRAY, Foreman Armature Winder, Tuscan Engineering Company, Ltd.

W. E. NUTTING, Hot Saw Grinder, Round Oak Steel Works, Ltd.

R. G. PAIN, Setter-Operator, AC-Delco Division of General Motors, Ltd.

E. E. PEACH, Foreman Electrician, Patent Shaft and Axletree Company, Ltd.

J. P. W. PILKINGTON, Foreman Labourer, Rolls-Royce, Ltd.

J. E. PROTHERO, Electrical Fitter, English Electric Company, Ltd.

E. PROUT, Machine Shop Foreman, Priestman Brothers, Ltd.

F. J. RICHARDS, Engineering Craftsman, Chatwood Safe and Engineering Company.

C. T. RICHARDSON, Transport Foreman, Hadfields, Ltd.

J. H. ROBSON, Foreman Glass Blower, Hartley Wood and Company.

M. SCOTT, Driller and Roof Scaler, Anhydrite Mine, Imperial Chemical Industries, Ltd.

E. Simmons, Chargeman Coppersmith, J. Russell and Company, Ltd.

E. J. THOMAS, Staff Foreman, Morris Motors, Ltd.

F. THOMAS, Head Foreman Loftsman, Vickers-Armstrongs, Ltd.

T. C. THOMPSON, Boiler Shop Plater, Harland and Wolff, Ltd.

C. WARDE, Tool Shop Assistant Foreman, Automatic Telephone and Electric Company, Ltd.

H. WARDLE, Chief Foreman Fitter, Walmsleys (Bury), Ltd.

W. J. WEBBER, Foreman, Aluminium Wire and Cable Company, Ltd.

Calcination plant and part of raw material stockpile.

Refractory Production

New Morgan Plant at Neston

IT is more than sixty years since The Morgan Crucible Co., Ltd. first began to manufacture specialised refractories in the form of assay ware, and since that time an extensive business has been built up—based on first class craftsmanship, allied to a readiness to apply the results of research and development to the product. As far back as World War I, work was being carried out on such advanced subjects as the use of cobalt oxide to improve radiant properties, the enrichment of clays with alumina, lime stabilised zirconia, heat-insulating refractories, and all-silicon-carbide crucibles and tubes. The same period also saw the company's first entry—in association with Douglas Firebrick Co., Ltd.—into the bulk production of firebricks. This was the start of the range of Douglas and Triangle brand firebricks and special shapes.

After World War II The Morgan Crucible Company, recognising that this country's key industries and power to export depended upon the bulk production of better refractories—especially those calculated materially to assist in achieving fuel economy—reluctantly decided it must leave the congested Battersea site for a new and better location.

A suitable site was found at Liverpool Road, Neston, Cheshire, and a new wholly-owned subsidiary company, Morgan Refractories Ltd., was formed in 1948 to handle the project. Morgan Refractories also took over the interests of The Morgan Crucible Company in the associated companies, Coupe & Tidman Ltd., Douglas Firebrick Co. Ltd., and The Whitrigg Fireclay Co. Ltd.

The New Project

In developing its new site Morgan Refractories Ltd., had four main objects in view :—

(*a*) To rehouse the Battersea Refractory Department in more modern buildings, with the most up-to-date equipment, and provide a layout that would facilitate not only regular economic flow but the closest of inspection and control at all stages of manufacture.

(*b*) To provide buildings and specialised plant for the bulk production of much improved and stabilised aluminous refractories, from 43% alumina upwards, and also a complete range of low-heat-capacity or hot-face insulating refractories.

(*c*) To make freely available the new cements, castables and mouldables, which had converted the " can and bag " refractory from a substitute material to one earning wide recognition on its own merits.

(*d*) To furnish these new manufacturing units with all the necessary ancillaries to ensure efficient transport and handling, first-class engineering services and, above all, process control and product testing of the most stringent and practical type.

The new project was only launched after a most thorough investigation of the best practices and plants in Europe and America. The lessons learned in this way were closely studied and applied in conjunction with the considerable craftsmanship and technical knowledge which Morgans had themselves built up. The latter included data for production kilning of all types of ware to temperatures as high as 1,800° C. Thus, the familiar axiom that during manufacture a refractory should be fully shrunk and stabilised at, or above, its service temperature could be put into practice.

Considerable study was also made of furnace efficiency, in view of the national fuel position, one of the factors investigated being thermal insulation. It became more broadly appreciated that in many cases one did not gain efficiency just by applying some insulation to the outside of an existing firebrick furnace lining. In fact, in batch furnaces it could even make matters worse. What was needed was a low-heat-capacity insulating refractory from which the furnace itself could be built—in fact, a hot-face insulator that would be stable at very high temperatures.

It had been demonstrated that such refractories could be made, on a small scale, and it was known that they were being manufactured in bulk in the U.S.A., but dollar restrictions prevented them being imported freely. As there was no plant in this country, or in Europe for that matter, capable of making the best qualities on the appropriate scale, Morgans, with the encouragement of the Ministry of Supply went ahead

with a plan for a new plant to manufacture these new refractories.

Site and Products

It had been decided that in the interests of efficiency the project must be a green field one, and the site selected at Neston covers 43 acres. The Midland Region main line with over half a mile of sidings forms its western boundary, and the Liverpool road its southern boundary. At present, only the western third of the site (alongside the railway) is developed, but there is room for considerable extensions, some of which are already on the drawing board.

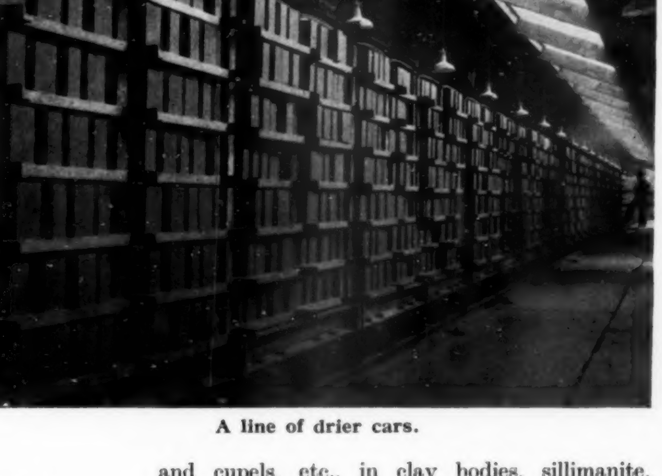
As projected, the refractories now being manufactured can be divided into four broad groups :—

(1) The MR Series—a full range of aluminous refractories embracing not only the high-alumina types, but also bridging the gap hitherto existing between such refractories and the best Scottish firebrick.

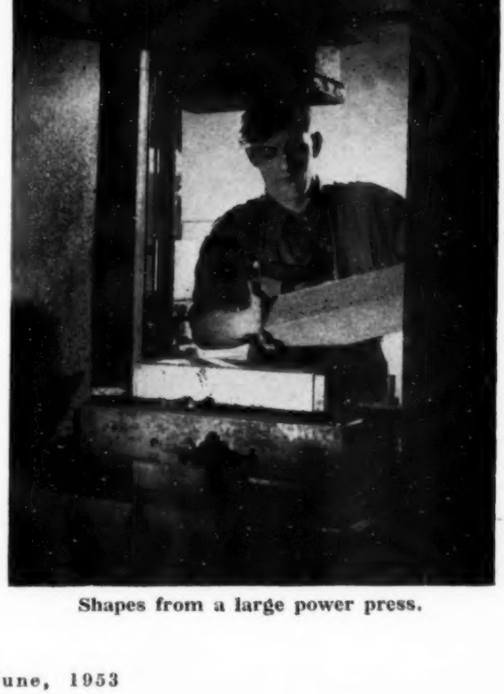
(2) The MI Series—represented at the moment by the MI.28 brick. This, as its name implies, withstands a face temperature of 2,800° F. (1,540° C.). and is the first of a range of high temperature hot-face low-heat-capacity insulating refractories. An MI.26 brick will shortly be on the market, and it is also planned to include a number of other hot-face low-heat-storage refractories for lower temperatures.

(3) The specialised refractories previously made at the Battersea Works, and embracing furnace shapes, bricks, tubing, crucibles, muffles, scorifiers and cupels, etc., in clay bodies, sillimanite, bauxite, fused alumina, silicon carbide, magnesite, pure oxides, etc.

(4) The widest variety of refractory concretes, insulating concretes, mouldable refractories and refractory cements.



A line of drier cars.



Shapes from a large power press.

Production of MR and Battersea Products

It will be clear that, with the wide variety of refractories manufactured, at some point, usually during calcination, grinding or grading, very different materials intended for very different products require similar treatment. It would have been uneconomical in space and have led to wasteful duplication of plant to separate the production lines for each group of products. The various stages of processing are, therefore, separated or combined to the best advantage.

Raw Materials.

Specially selected raw materials from the United Kingdom and other parts of the world—clays, bauxite, sillimanite, etc.—go into the works for the most part by rail. Before binning, samples are sent to the process control laboratory for testing to determine that the materials meet the standard specification laid down. On acceptance, they are taken to the sidings, which are some 15 ft. above the works datum and are shot from the trucks directly into bins on the level of the works roadway. These bins are grouped adjacent to the milling and grinding plant feeding the main MR and Battersea production units. The internal railway system is planned to encircle the whole of the northern part of the works, making it possible to unload materials for the other products wherever they will be needed.

Calcination.

A large proportion of the materials used has to be calcined before being made into refractories, and this is carried out in a rotary kiln specially designed for calcination up to the highest temperatures. The raw materials are stored in bins close to the plant and may be fed direct to the kiln by an elevator and conveyor. Alternatively, they may be passed first through crushing and processing machinery, and then elevated into storage bins inside the building. The bins discharge on

Extracting samples on blending floor.

to a belt conveyor which feeds the kiln via an elevator. The calcined materials from the delivery end of the rotary kiln are mechanically elevated, sampled and tested by the process control department, and, if approved, distributed and piled into brick-built bays. In this building a pulveriser and an air-separator and storage hoppers are being installed for the processing of bond clays.

Grinding, Milling and Blending.

The complicated grinding, milling and blending plant, is set up to produce first a range of all-in meshes, then to fractionate these, magnet and recombine them to get the desired and closely controlled combination of mesh sizes, an essential in the production of high-grade refractories. The plant consists of crushers, pulverisers, screens, conveyors, elevators and storage hoppers. It is designed for completely automatic operation, and any predetermined flow sequence can be set up on the automatic controller.

After grinding and grading, the material for MR refractories is automatically weighed and blended. Each ingredient is repeatedly magnetted until any iron picked up during grinding has been removed. Finally, the blended material is conveyed to stainless-steel-lined storage bins at the head of the production line. The materials for the Battersea products are magnetted and weighed into bags or non-ferrous metal containers and conveyed to storage in the mixing section of the production unit.

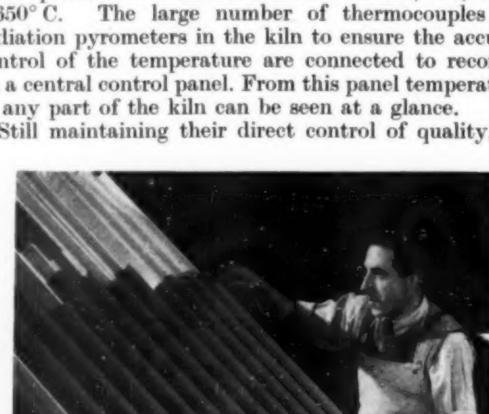
In designing the plant, the prevention of contamination, particularly by iron, has been a major consideration. Thus, all conveyors and bins are totally enclosed, and, wherever possible, any part of the plant coming into contact with the raw material is either non-ferrous or stainless steel. As a further safeguard, all materials are passed over powerful electro-magnets, specially designed for dealing with this type of material. The material in process is subjected to examination by the process control department at all stages.

MR and Battersea Production Lines.

The building housing the MR and Battersea production lines consists of 5 bays, covering an area of 125,000 sq. ft. immediately to the south of the materials preparation plant. For the most part, it is a single storey building, but at the end where the materials from the mill are delivered, it is raised to two storeys so as to provide the gravity feed to the mixers. Here again, in this building special care has been given to the prevention of contamination. It was, therefore, designed so that in the whole structure only non-ferrous metals were used where necessary above ground level. The framework of the building has been constructed from reinforced concrete of a modern design and all fittings are of aluminium throughout. All ledges which might hold and shed dust have been reduced to a minimum, and the construction is such that the working area can be kept scrupulously clean. As in the mill, all parts of the plant coming into contact with the refractory material are either non-ferrous or of stainless steel.

(*a*) *MR Refractories.*—The weighed and blended material delivered from the mill is held in stainless-steel-lined surge bins. From here it passes into the mixers which, like all the other plant, are lined with stainless steel. Water is then added to produce a mixture of the correct consistency. After pressing, the bricks are passed through a continuous drier and finally fired in an oil-fired tunnel kiln giving a heat treatment which thoroughly stabilises these products for their conditions of use, i.e., up to 1,650° C. The large number of thermocouples and radiation pyrometers in the kiln to ensure the accurate control of the temperature are connected to recorders on a central control panel. From this panel temperatures in any part of the kiln can be seen at a glance.

Still maintaining their direct control of quality, the



Skilled finishing operations.

process control section takes samples off the press, from the drier and even from the hot zone of the tunnel kiln. From the exit end of the tunnel kiln the bricks are taken to store, and before leaving the works are subjected to final inspection by the works inspectorate. This means that before leaving the works these bricks have been subjected to two completely independent inspections. Both the process control and product inspectorate have at their disposal the resources of a fully equipped testing laboratory, including some of the largest refractory test rigs in existence. This enables practical tests of spalling and load carrying powers to be made on large panels and full sized bricks respectively.

(*b*) *Battersea Refractories*.—The weighed materials received from the mill are fed into mixers, water is added, and the batch prepared to a suitable consistency, according to the method of manufacture being used. The mixed material is dropped into specially designed aluminium containers which are held in storage racks. This storage unit was designed so that the many and varied batches can easily be identified, and the containers picked up by a fork-lift truck and delivered direct to the individual maker. The empty containers are returned to the mixing section and thoroughly cleaned in order to avoid contamination of subsequent batches. These manufacturing methods fall under five headings—hand moulding, machine moulding, machine pressing, extrusion and slip casting. The method chosen depends on the nature of the body, the particular pattern being manufactured, and the usage requirements.

After drying, the refractories are fired in one of a variety of kilns according to the product. They range from simple coke or oil-fired beehive kilns to a specially designed gas-fired tunnel kiln, and include specially constructed furnaces capable of giving the extremely high temperatures required for grades such as fused and recrystallised alumina. Recuperation and insulation are widely used to secure high fuel efficiency.

The same double system of inspection applies to these refractories during forming, drying and firing. No refractory is delivered or put into stock until it has passed the independent works inspectorate.

Production of MI Bricks

The MI range of bricks are made in a separate self-contained unit. This range of low-heat-storage insulating refractories will eventually embrace a number of different hot-face insulating bricks for service at a range of temperatures up to 3,000° F., but, at the moment, the plant is working on bricks for use at face temperatures of 2,800° F. MI bricks are essentially kaolin bricks with a very open structure obtained by mixing combustible with clay and afterwards burning it out. They are exceedingly light in weight and, considering their structure, very strong : in addition they have a very low thermal conductivity and their heat capacity and storage is extremely low. All in all, they represent one of the most important advances in refractory manufacture made in this country since the war.

Raw Materials.

In the production of the bricks, it is absolutely essential that the combustible and other material should be accurately prepared and graded, and the preparation plant stands in much the same relationship to these bricks as the grinding plant to the MR bricks. This specially designed and equipped plant is housed in a building of its own at the northern end of the MI unit.

Stock bins for prepared materials.

Mixing, Pressing, Firing and Grinding.

The MI production line occupies bays some 60,000 sq. ft. in area. The raw materials from the mill are automatically weighed and conveyed to a mixer, where the mixing of the batch is carefully controlled to give the correct consistency, and when finally approved are passed to the automatic presses. The pressed bricks are then dried in a continuous drier and are finally kilned to very high temperatures in an oil-fired tunnel kiln.

The final operation is the grinding of the brick on all faces to accurate dimensions. This ensures tight thin joints and reduces the labour required in furnace construction. After grinding, each brick is inspected individually and the strength automatically tested. They are then packed in cartons and sent to storage. Throughout the whole of this process from the raw material preparation to final packing, these bricks are once again subjected to the same strict checking by the process control department and works inspectorate as are the MR bricks.

Refractory Cements and Concretes.

One new unit exists for the production of refractory cements and concretes and, additionally, another separate manufacturing unit, first temporarily housed in the original brickworks building adjacent to the calcination plant, is also being modernised. These largely self-contained units produced the wide range of refractory concretes, cements, mouldables, settings and mortars already mentioned.

Process Control and Works Inspectorate.

There are in the works two completely independent groups of personnel concerned with the control of quality from the incoming clay to the outgoing product, and each group has clearly defined functions and responsibilities. The process control staff is intimately concerned with the manufacture of the product : their

duties include the testing of all incoming raw materials, checking materials at each stage of the manufacturing process and ensuring that the materials at all stages of production reach the necessary high standard. On top of all these rigid precautions, there is a completely independent body of inspectors who finally inspect all finished products. This inspectorate is completely separate from works management, and theirs is the final say in any question of quality : no material can enter stock or leave the works without their permission. They have nothing to do with running the plant, but are there essentially to ensure that the customers receive the intended and specified quality and service.

Other Technical Services.

Morgan Refractories Ltd., are well equipped for tackling the many technical problems associated not only with the manufacture but application and use of the highest grade and most specialised refractories. To supplement the services of their own highly-qualified staff, they can call on the central research and development department of the parent company at Battersea.

This makes available modern techniques in spectroscopy, microscopy and X-ray crystallography, together with a wide range of equipment specially developed for testing creep and strength, thermal conductivity, thermal shock resistance, and other properties of refractory materials under all probable conditions of use. Fullest access is available to a group of scientists and technicians for fundamental studies and for advice on the many problems in chemical engineering, furnace construction, fuel technology and quality control which may arise. In addition, this department correlates information both from outside the company and from other divisions of the parent company with which the group is linked.

New and Revised British Standards

LEAD AND LEAD ALLOY SHEATHS OF ELECTRIC CABLE (B.S.801:1953). PRICE 2s.

The earlier edition of this standard, which was issued in 1938, included pure lead and four lead alloys, to which a fifth was added by the issue of an amendment slip in 1942. Subsequent experience has shown that a smaller range of alloys is adequate to meet users' requirements and the present revision, therefore, refers to lead and three lead alloys only. The methods of analysis given in the earlier edition have been omitted from this revision and consideration is being given to the practicability of preparing a separate British Standard for methods of analysis for lead and lead alloys. The fatigue data which were given in the 1938 edition have been replaced by an appendix giving guidance on the types of cables and conditions of service for which particular alloys are suitable.

BRASS TUBES FOR GENERAL PURPOSES: 70/30 BRASS, ALUMINIUM BRASS (B.S.885:1953). PRICE 2s. 6d.

IN this revised standard requirements for both as drawn and annealed tubes previously numbered separately as B.S.885 and B.S.886 have been incorporated in the one standard. The optional addition of tin to 70/30 brass has been deleted and aluminium brass has been included as an additional alloy. Many clauses have been redrafted and certain modifications made to the tests required and tolerances allowed. An appendix includes a table of sizes of 70/30 brass and aluminium brass pipe for the petroleum industry.

COPPER FOR ELECTRICAL PURPOSES.
TUBES (HIGH CONDUCTIVITY).
(B.S.1977:1953). PRICE 2s. 6d.

THIS is the fourth in a series of standards for copper for electrical purposes. The others in the series are :—

B.S.1432, Copper for electrical purposes. Sheet and strip.

B.S.1433, Copper for electrical purposes. Bar and rod.

B.S.1434, Copper for electrical purposes. Commutator bars.

The standard lays down requirements for copper tubes of high conductivity and does not apply to cable sockets or conduit for electrical wiring, for which the appropriate standards are B.S.91, "Electric cable soldering sockets," and B.S.840, "Light-gauge seamless copper and copper-alloy conduit and fittings for electrical wiring." Provision is made whereby the purchaser can, by special arrangement, specify that tubes shall be made from oxygen-free high-conductivity copper complying with B.S.1861 recently published.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

Fielding Press for Austria

A 300-ton hydraulic commutator press for Messrs. Elin & Co., of Weiz in the Province of Styria (British Zone, Austria), has been dispatched from the Gloucester Works of Fielding & Platt Ltd. Elin & Co., who have an international reputation, are the largest electrical engineers in Austria, specialising in the manufacture of transformers, generators, switchgear, etc.

This Fielding press is of the vertical four-column upstroking type, being self-contained and provided with hydraulic direct pumping equipment, using oil as the pressure medium. The four forged steel columns are screwed to give the necessary adjustment to the top table, which is of fabricated steel construction. The adjustment to the top of the press is by means of a vertical geared motor located on top of the table, the drive to the four column nuts being by means of roller chain. The pumping equipment comprises a two-pump arrangement, one pump being a variable-delivery type having a capacity of 0–18 gal./min. at 3,000 lb./sq. in., whilst the other pump has a capacity of 40 gal/min. at 200 lb./sq. in. These pumps are arranged to work together to afford a rapid approach of the press rams, the high pressure pump completing the actual pressing operation.

Change of Address

THE Manchester Branch Office of the Electric Motor Division of Newman Industries, Ltd., is now at Chronicle Buildings, 74, Corporation Street, Manchester, 4. Telephone : BLAckfriars 1920.

Induction Heating of Aluminium Alloy Billets at Mains Frequencies

By Dr. R. H. Barfield

Wild-Barfield Electric Furnaces Ltd.

The use of mains-frequency induction heating of billets for extrusion and forging is increasing. The possibilities and limitations of the method are considered and the factors governing the design of the equipment discussed.

THE possibility of employing normal mains frequency for induction heating has been long recognised and commercial applications of various kinds have been in use for twenty or thirty years. It has recently, however, come considerably more to the fore. The reasons for this are much the same as those which apply to the modern tendency to increase the use of induction heating at high frequencies, viz.:

(1) The demand for more rapid heating to enable production line rather than batch handling methods to be introduced. This is a tendency which is part of the natural evolution of industrial processes as a whole.

(2) Improvements in methods of temperature control have enabled the induction heating technique to be introduced without risk of over-heating.

(3) Improvement of working conditions; this is a demand which is becoming of increasing importance.

(4) There is a great saving of floor space as compared with the batch type of furnace.

Mains-frequency heating is suitable for preheating non-ferrous alloy billets for forging or extrusion. The process has been commercially exploited in the U.S.A. for aluminium alloy billets ranging from 2 in. to 12 in. in diameter. The advantages of introducing induction heating are that very rapid heating is obtained; the billets can be fed to the inductor continuously instead of being heated in large batches, so that there is a very large saving in floor space; there is no waste heat and the maximum temperature at any part of the furnace is never greater than that of the charge itself. Consequently, working conditions are greatly improved.

It is, of course, a condition of using this means of heating that the treatment must be metallurgically sound; that is to say, it can only be applied to metals or alloys when the rapidity of heating has no adverse effect on the metallurgical properties of the component as far as such properties affect the purpose for which it is finally to be used.

Assuming the above condition is fulfilled—as in fact it is for many commercial types of ferrous and non-ferrous metals—induction heating at mains frequency can be employed for heating billets for forging provided the diameter is large enough. The minimum diameter required for mains-frequency heating is a function of the magnetic permeability and resistivity of the metal or alloy. Table I below shows the various minimum diameters corresponding to different types of metals and alloys. It will be noted that mains frequencies are suitable for heating steel up to 700° C. in induction heating furnaces. In the case of induction furnaces for heating large steel billets to forging temperatures, it will be normal practice to preheat by mains frequency to 700° C., the final temperature being obtained by high frequency.

TABLE I—MINIMUM BILLET DIAMETERS FOR MAINS FREQUENCY HEATING.

Billet Material	Minimum Diameter	Normal Working Temperature
Aluminium Alloys.. ..	2 in.	500° C.
Aluminium Bronze ..	4 in.	950° C.
Brass	3 in.	950° C.
Copper	2 in.	1,000° C.
Steel	1½ in.	700° C.

In general, the combination of the heated billet and the inductor surrounding it may be looked upon as a transformer. The design of this transformer involves many of the features associated with standard transformer design, and in addition more complicated features enter into the matter. It is impossible to standardise this type of transformer, as each application presents entirely different problems. Further, there is no possibility of assuming a simple magnetic circuit, and there is also the problem of calculating the phase angle of the load, which determines the value of the power factor correction capacitor to be employed. On the other hand, it is essential that the final results should satisfy the specified rating of the installation. In view of the number of features—some of them difficult to ascertain—which determine the final rating of the induction-heating transformer, a considerable amount of work is involved in working out preliminary estimates for the inductor design. With large-scale equipment, involving many hundredweights of copper in the primary winding, trial and error methods of obtaining the correct number of turns are quite out of the question.

Power Factor

An induction-heated furnace of this type constitutes, by its very nature, an electrical load of low power factor, which will normally be about 0·4. Power factor correcting capacitors having a kVA rating more than double that of the total power rating of the furnace are, therefore, essential and constitute a considerable fraction of the capital cost of the equipment.

There are two reasons for this low value of the power factor. In the first place, in the process of induction heating there is a penetration of magnetic flux into the

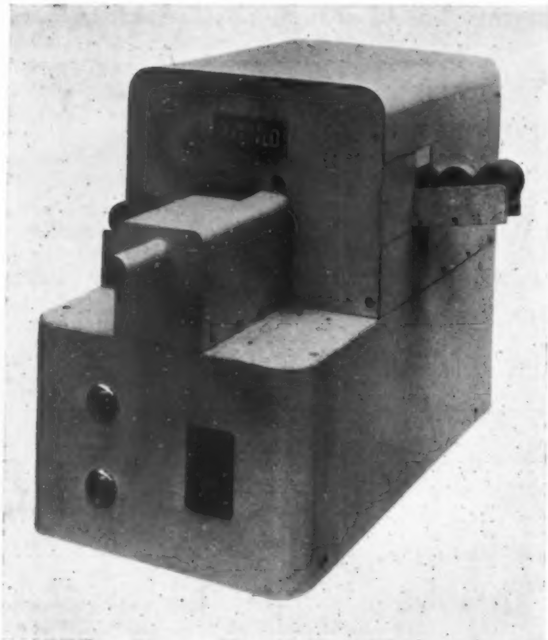


Fig. 1.—Heater for 2 in. billets.

surface layers of the billet and the resultant value of this flux is at 45° phase angle to the primary current. Hence the billet itself reflects into the primary current reactive and resistive components which are equal to each other, and of which the latter constitutes the useful load of the furnace. Thus, the reactive kVA can never be less than the useful kW supplying heat to the billet itself.

In addition to this, there must obviously be some spacing between the inductor and the billet to provide the mechanical clearance necessary for loading and unloading. This space will be filled with the leakage flux due to the current in the inductor winding: but since there is no magnetic core to magnify the useful flux, the relative importance of the leakage flux is much higher than in a normal transformer. This adds a large additional reactive component to the load impedance and further reduces the power factor.

Factors Determining Heat Generated in Billet

The power generated in the load or billet depends essentially on the strength of the magnetic field within the inductor surrounding it. If the field strength is H, d is the diameter of the billet, and p is the skin-depth, the power dissipated in the form of heat at frequency f is given, approximately, by

$$P = fH^2\frac{p}{d} \times 10^{-7} \text{ watts/cc.}$$

where $H = 1{\cdot}25 \times$ ampere-turns/cm., if $\frac{p}{d}$ is less than about $0{\cdot}20$.

To produce a field strength capable of giving the rapidity of heating which is associated with induction furnaces, e.g. from 1 to 15 minutes according to diameter, a heavy primary current will be required, and this will generate useless heat which must be removed by water cooling. The amount of power wasted in this way is inevitably high. It is possible, by providing multi-

TABLE II—HEATING TIMES FOR ALUMINIUM ALLOY BILLETS*.

Outside Diameter (ins.)	Minimum Time of Heating (minutes)
2	¾
4	2¾
6	6¼
8	12½
12	30

* Surface-centre temperature difference not to exceed 15° C.

layer windings on the inductor, to reduce it to rather under half the total power, but beyond this it is not possible to go without seriously decreasing the power factor.

In spite of this high percentage of waste heat, the output obtainable in lb./hr. for a given power consumption compares favourably with that of batch type furnaces.

Thermal Considerations

Various conditions must be fulfilled on the thermal side of the problem.

(1) The billet temperature must not be allowed at any part to rise beyond a definite maximum value, say, 500° C.

(2) The radial temperature gradient must remain within fixed limits. For example, it may be specified that the temperature drop between the surface and centre of the billet shall not exceed 15° C.

(3) The temperature must be uniform along the length of the billet at the moment of ejection.

The first of these conditions is ensured by means of an automatic temperature control device of some sort. This conveniently takes the form of a contact thermocouple, spring-loaded to press on the front end of the billet. By means of relay and contactor the power is switched off or reduced when the temperature exceeds the desired value.

The second condition can only be fulfilled by ensuring that the heating cycle is long enough. The radial temperature difference between centre and circumference for any given rate of heating can be calculated without much difficulty, and Table II shows the minimum time of heating for various diameters of aluminium billets in order to ensure that the radial temperature difference does not exceed 15° C.

The difference is permissible since the rapid rate of equalisation ensures that temperature uniformity will be achieved by the time the billet arrives at the press.

A Typical Furnace

A billet heater for 2 in. o.d. billets is shown in Fig. 1 and illustrates by its construction, appearance and manner of working, the general principle common to induction heaters for billets of all sizes. The billets are loaded side by side on an inclined ramp or chute and a pusher rod projects one billet at a time into the inductor. At the same time the spring loaded thermocouple is brought into contact with the front face of the billet and the power is switched on. At the end of about one minute, the temperature of the billet attains 500° C. and the thermocouple operates the automatic temperature controller which cuts off the power. The billet is then ejected and the next one loaded, both of these operations being performed automatically.

Automatic Control of Fuel-Air Ratio in Metallurgical Furnaces

By Leo Walter

IT is well-known that correct combustion in large metallurgical furnaces is mainly dependent on furnace pressure and on fuel-air ratio. Whilst manual or automatic control of pressure is comparatively easy, fuel-air ratio control presents quite a problem. The following notes have been prepared to outline the ways and means at the disposal of the instrument engineer, and shows by means of typical examples how the problem can be satisfactorily solved. The following is confined to liquid or gaseous fuels, but application to solid fuels fired by means of automatic stokers is also possible.

Characteristics of Ratio Controllers

Assuming for simplicity's sake that fuel oil is the heating medium, the problem of fuel-air ratio control is obviously a rate of flow control problem. The usual method, which is well-known to the metallurgical engineer, for measuring the rate of fluid flow in pipelines is by the insertion of an orifice, thus creating a pressure differential, the square root of which is strictly related to the rate of flow. Automatic control of rate of fluid flow in a pipeline uses the same or a similar principle, with a pitot tube instead of the orifice or nozzle, by means of an additional control section to the measuring section of the instrument mechanism. The source of power can be compressed air, oil or water under pressure, or electricity, and magnification of the control impulse can be effected by means of mechanical relays, or by electrical or electronic amplification. The regulating unit is a pneumatic, or a motorised control valve, or, in the case of larger gas flow pipes, a butterfly valve with diaphragm or electric motor.

A ratio controller, which performs double control, is a control instrument in which changes in one process variable (rate of flow in our case) automatically adjust the control point of another variable or process factor (in our instance again rate of flow in a second fluid pipeline). The controlling and adjusting systems are separate, each with its own functions, but interlocked in such a manner as to produce the desired predetermined result. For fuel-air ratio, the latter is maintenance of the correct ratio between fuel flow and air flow irrespective of burner and furnace load. It should be noted that the control system does the actual controlling in the conventional manner; the adjusting system serves only to change the control point (set rate of flow value) of the controlling system through a mechanical or electrical linkage connected to the control mechanism.

Summing up, the adjusting instrument resets the control point of the controlling instrument actuated by the flow of the uncontrolled or primary instrument. In our case the "uncontrolled" flow is fuel flow, and air flow has to be adapted to it. The term "ratio" indicates the amount of control point adjustment caused by a unit change in the uncontrolled instrument. In other words a ratio control system has to be adjustable according to working conditions. For example, the change of

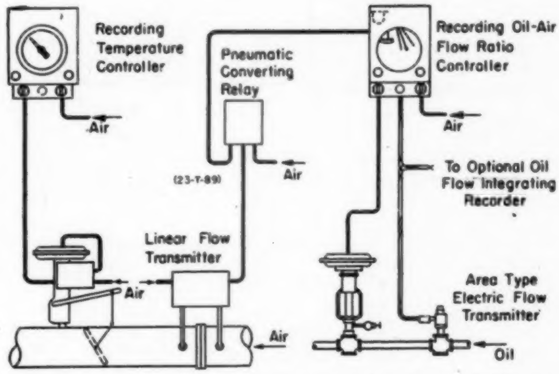


Fig. 1.—Ratio control system layout for oil-fired furnace, using two control instruments for metered control.

rate of flow of air for combustion depends on the oil burner and on the fuel oil characteristics, and the control system must be adaptable to these. Another control term to be understood is "direct ratio." This indicates that for any increase in the controlled variable, such as rate of flow, an increase in the controlled medium will be effected.

After this introductory basic dealing with ratio control as such, the elements of our control problem of fuel-air ratio can be expressed as follows: (*a*) measurement of furnace temperature; (*b*) use of the results as the basis for combustion control, i.e., for control of air and fuel flow; (*c*) establishing the correct ratio of air flow to fuel flow. Means should be provided of varying the ratio at will, for example, according to change of fuel oil quality, and also for applying automatic variation in the amount of air for a given amount of fuel to compensate for air infiltration.

Four Typical Control Applications

Looking at layout Fig. 1, applied to oil-fired metallurgical furnaces, the furnace temperature is measured by a thermocouple unit and controlled by a potentiometer instrument which regulates air flow to the burners. The rate of air flow is measured by means of a linear flow transmitter working on the pressure differential from an orifice inserted into the air pipeline. The output differential pressure is converted in a pneumatic relay, whose output air pressure actuates the secondary instrument. The latter is a dual recorder-controller and records on a circular chart both rate of air flow and rate of oil flow. The latter is measured by an area type oil flow meter with electric flow transmission to the recorder-controller. The oil flow is automatically controlled by means of a diaphragm control valve in accordance with the measured rate of air flow and the manual ratio settings. By setting a ratio index pointer on a direct reading scale, air-oil ratios from 25% to 200% are obtainable, and integration of

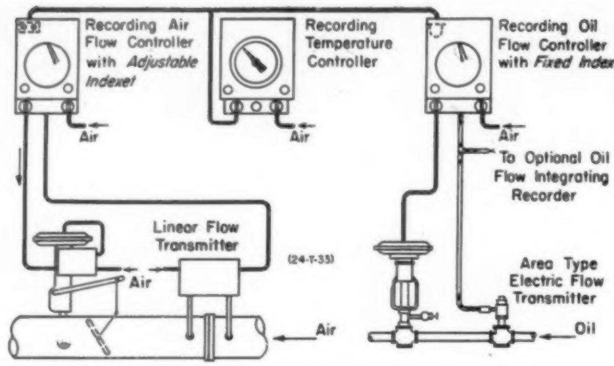


Fig. 2.—Three-instrument control scheme for gradual fuel combustion air ratio control for oil-fired furnaces.

oil flow can also be provided for if desired. The control mode used is "integral" or "automatic reset" control by means of pneumatic feedback. In the particular installation shown, the pneumatic temperature controller with circular chart, the recording ratio control receiver and the area type electric flow transmitter are Brown Electronik instruments, whilst the linear flow transmitter in the air flow is of Hagan or Republic (Electroflo) type. The pneumatic control valves are of the Honeywell-Brown type, one equipped with lever type valve positioner as shown.

Another system, also for oil-fired furnaces, utilises the same Electronik Air-O-Line temperature controller (Fig. 2) which in this case automatically positions the set point indices of two flow controllers measuring fuel and air so as to maintain furnace temperature as well as the required fuel-air ratio. A pneumatically operated Fixed Indexet unit in the oil flow recorder controller establishes the required fuel setting and simultaneously positions an Adjustable Indexet unit in the air flow recorder controller. The fuel-air ratio is readily set by adjusting the ratio setting knob of the Adjustable Indexet, with ratios of 0 to 200% obtainable. It is also possible to shift the zero by adjusting the ratio shift knob, and thus provide a fixed fuel or air bias.

A linear flow transmitter measures the flow of air to the burner. Its transmitter air pressure goes to the measuring element of the air flow recorder controller, and the control unit provides the controlled air pressure to operate the air supply control valve. An area type electric flow transmitter measures the fuel oil flow and transmits to the oil flow recorder controller. Controlled air pressure from this control unit operates the oil flow control valve.

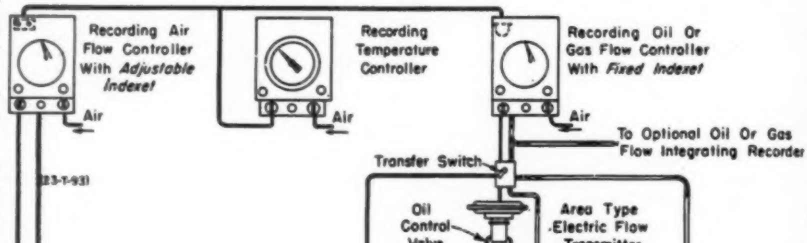


Fig. 4.—Three-instrument metered ratio control system for gas- or oil-fired furnaces.

This system provides the advantage of the bias setting through use of the ratio shift adjustment, as well as a wider range of ratio settings and simultaneous changes in both fuel and air supply. Both this system, and those following, can be operated from a manual loading station rather than a temperature controller, if desired.

The third control system as shown in layout Fig. 3 is for gas-fired furnaces. It differs only in that it employs square root transmission of air and gas flow and has instruments with square root charts, i.e., unevenly divided chart units. The control valves are one for air and one for gas, and they are of the butterfly or adjustable orifice type.

A control system for dual-fired metallurgical furnaces using either fuel oil or gas for their operation is illustrated in Fig. 4. The system shown has been designed to enable the operator to change the control by means of a switch from one fuel to the other. It combines the functions of both systems shown

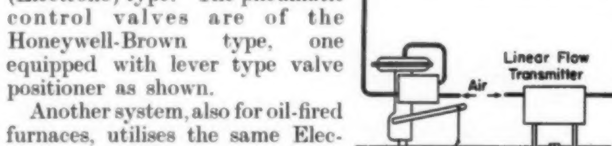


Fig. 3.—Ratio control layout using two recorder-controllers and one indicator.

in Figs. 2 and 3 and provides two mechanically interlocked transfer switches. One controls air to gas or oil burners, the other is for the electrical signal from the gas or oil flow transmitter. It should be emphasised that, in case the B.Th.U. contents of full scale gas flow and oil flow are not equivalent, manual readjustment of the control ratio has to be performed. A pneumatic selector switch mechanically interlocked with an electric selector switch is used as illustrated.

In all four example layouts, records are provided of both fuel and air flow. The use of special area type flow meters and transmitters is successful for measurement of rate of flow of heavy fuel oils, tar, pitch and other viscous fluids. Control can be performed from manual-automatic loading stations, if required, and the use of a ratio-shift or bias adjustment compensates for air leakage into the furnace.

In conclusion the writer is indebted to the Brown Instruments Division of Messrs. Minneapolis Honeywell Regulator Inc., for permission to use the layout diagrams.

Hot Metal Receivers

Continuous Supply of Iron for Casting

WHILE the foundry cupola is an extremely economical method of melting, its output is intermittent, and it suffers from the drawback that it has no considerable storage capacity for metal. Both these points are of considerable importance in a modern foundry, especially in motor-car and similar plants where moulds operating on the conveyor system have to be poured.

In order to improve the performance of the normal cupola, increasing use is now being made of an adjunct consisting of a hot-metal receiver, either oil or gas fired, of the type shown in Fig. 2. Such a receiver, besides providing at all times an adequate reserve of metal, ensures that this is always at the precise temperature required, usually from 1440 to 1500 °C., and it will be readily appreciated that, in combination with a normal cupola, the latter becomes a far more flexible instrument of production, and far more adapted to modern metallurgical needs than any standard model, however carefully this may be operated; in fact, where working conditions are ripe for the use of this development, the overall production of a foundry may on occasions be increased between 30 and 40% by this additional item of equipment. Fig. 3 shows a receiver of the type described, which is part of a battery installed by Monometer Manufacturing Co., Ltd., in a mechanised foundry in the South of England.

Method of Operation

In operation, the usual method is for the receiver to be heated up at the commencement of the day's work to a temperature which is about 50 °C., above that of the metal tapped. It should be noted that the design is such that the cupola metal can be tapped into one end of the receiver while, by means of its tilting mechanism, the latter is pouring. In this way, a constant through-pour is ensured which obviates any hold-up of production such as is liable to occur periodically when the cupola is used without this supplementary equipment.

The main constructional features of a modern hot-metal receiver can be readily followed from the illustrations.

The burner fires into one end of the furnace chamber, and the operation is recuperative in that the exhaust gases from the chambers are used to preheat the air supply furnished by a motor-driven fan by passing it through a recuperator arranged in the furnace arch. The oil-fired burner used operates with an air supply at 2 lb./sq. in. The particular receiver installation illustrated is entirely self-contained and fully mechanised,

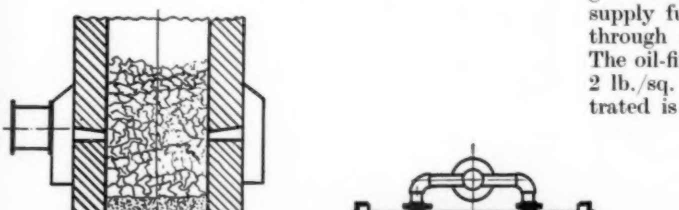


Fig. 1.—Section of hot metal receiver working in conjunction with cupola.

Fig. 2.—Side elevation of receiver.

Fig. 3.—Typical receiver in modern mechanised foundry.

under push-button control, but the reduction gearing for the tilt embodies a clutch which enables a handwheel to be brought into operation for this purpose in the event of any current failure. Silica bricks are employed for arch and side feathers, the life of the receiver lining in regular operation in the average foundry being six to nine months, while the design is such as to permit of a complete re-bricking during the period of a week-end shut-down.

The average hourly consumption of a 5-ton receiver of the oil-fired type as illustrated by Fig. 1. is 12 gal./hr. when passing through metal at the rate of 10 tons/hr. This is a field in which there exists little or no record of full-scale tests, mainly due to the fact that the fuel consumptions involved are so small in relation to the advantages resulting in operation.

Flexible Installations

While the illustrations show a hot-metal receiver installed in connection with a single cupola, the arrangement is very flexible to suit the requirements of individual foundries. For instance, a single receiver of the stationary type may be fed by a number of cupolas by means of suitable launders (or troughs) which take the metal to the hopper of the receiver. Alternatively, the receiver itself may be mobile by being mounted on a four-wheeled bogie, in which case the receiver is afforded the necessary radius of action by flexible piping to the burners, which permits of a maximum travel up to about four yards: in other cases it may be wheeled to a second cupola and re-coupled to the fuel and air supply lines at that point.

Continuous Lead Casting Machine

THE Fraser & Chalmers Engineering Works of The General Electric Co., Ltd., has designed and recently installed an interesting continuous lead casting machine for a chemical producer in Cheshire. The machine is 32 ft. 3 in. long, 6 ft. 2 in. high, and has a total all-up weight of 9 tons: its capacity is 10 tons of pigs per hour.

Each of the 88 moulds, which form the basis of the machine, has a capacity of 1 cwt. in two pigs of 56 lb. weight each, and they are arranged to travel from the pouring point along the rails, which have a gradient toward the discharge end of $\frac{1}{16}$ in. per foot, thereby reducing slightly the power required from the drive. The moulds form a continuous train around the track of the machine except for a space at the discharge end, where by means of gravity and a slight bumping effect, the solidified pig is discharged. The empty moulds return by gravity along the lower rack to the feed end.

The moulds are in no way connected with one another; each travels upon four bushed track rollers and each roller is fitted with a grease nipple for lubrication. At the driving and discharge ends additional retaining rails are fitted on the outside radius to guide the moulds around the track. Lead is poured at a temperature of 400/420° C., the flow being controlled by manual operation.

The method of propulsion is for a toothed driving sprocket to engage with the bushed track rollers at the drive end and traverse them around the inner radius of the slide rails, the actual drive being transmitted by each mould pushing against its preceding mould. A running speed of 2·52 ft. per minute gives the machine a

designed capacity of 400 pigs (10 tons) per hour. The time cycle allows ample time for cooling and enables the pigs to be ejected in the solid state. At the same time any dressing which the moulds may need may be accomplished during the return run to the drive sprocket.

Nickel-Copper Alloy Prices

BRITISH DRIVER-HARRIS CO., LTD., of Manchester, announce a reduction of 2d. lb. in the prices of their nickel-copper series of alloys, consequent upon the recent reduction in the price of electrolytic copper. This reduction applies especially to their "Advance" products, and particularly to "Special Advance" for low-temperature thermocouple purposes.

Gold, Silver and Jewellery Industries
Report on Research Progress 1951-52

IN the Sixth Annual Report of the Design and Research Centre for the Gold, Silver and Jewellery Industries, reference is made to the uncertainty which prevails with regard to the Centre's future. Since its inception in 1946, it has continued to increase its services to the industries concerned, and much valuable work has been carried out on both the design and research sides. It would, therefore, be a matter for regret if the value of the combined design and research services built up, and of the considerable amount of detailed technical information acquired since 1946, were in future to be lost to the industry.

In an outline of the work of the Research Section, reference is made to a number of investigations carried out during the year, and some idea of the scope of the Sections' activities may be gained from the following notes culled from the Report. The similarity will be noted between the problems under investigation and those arising in other industries, although, as might be expected, the emphasis is laid on somewhat different aspects.

Sand Casting of Nickel-Silver.—Large quantities of small fittings for electroplate ware are sand-cast in nickel-silver. It is essential that these have a smooth surface, sharp detail and freedom from surface or sub-surface defects. The casting is mostly done by a few specialist firms, and the first two requirements are well met by the special technique of facing the mould with soot. It is, however, a very general complaint that the castings frequently have surface or sub-surface blow holes. The methods of two foundries have been inspected and a large number of trials carried out by the Centre's staff in one of them. It has been concluded that the blow holes are entrapped air and sand carried down by the molten metal, as they are equally prevalent in castings of other non-ferrous alloys. The quality of the castings can be substantially improved by control of the moisture and permeability of the sand, but especially by redesign of the gating system so that the runner is kept full at all times. Even so, it is difficult to ensure perfect castings by this method and the advantages of investment castings have been pointed out in spite of their higher cost.

In the course of this work it has been found that replacement of the nickel in the nickel-silver by electrolytic manganese results in a considerable saving of cost, whilst introducing no difficulties in soldering or plating.

Investment Casting.—The Centre has firmly established itself as a central consulting authority on this method of jewellery production and has a complete set of equipment for demonstration and experimental purposes. As it was impossible to purchase an effective device in the U.K. for injecting wax into the rubber moulds, the Centre designed and patented a simple apparatus, and has arranged for its manufacture and sale to the Trade. Thirteen of these injectors have been sold.

A recommended method of making the rubber moulds in which the wax patterns are cast has been fully described and illustrated in a Research Report, whilst on the investment side, a large number of different plasters have been practically tested and simple procedures and equipment devised to obviate or minimise the inclusion of air bubbles in the investment, as these cause defects on the casting. Many demonstrations of the process, in part or complete, have been given to firms in the Trade.

Lustrous Metallic Surfaces on Costume Jewellery.—In previous work it had been shown that a brilliant metallic lustre could be obtained on costume jewellery, without laboriously polishing, by the process of lacquering to produce a smooth surface and then metallising this surface, preferably with aluminium, by vacuum evaporation. Considerable attention has now been given to the types of lacquer and methods of application which produce the maximum smoothing effect and a simple quantitative test for this property has been devised and published. The removal of volatile components is necessary before vacuum treatment and this necessitates careful choice of lacquers and stoving processes especially when a plastic article is being decorated. Some experiments have been made on evaporation of yellow-coloured alloys to simulate gold, but without great success, owing to the fractional distillation of alloys. Further attention has therefore been given to the established method of absorption dyeing of a lacquer film applied over an evaporated aluminium coating which provides a method of obtaining a finish of uniform colour and metallic appearance.

Electrogilding.—In the gilding of base-metal watch bracelets, watch cases and jewellery, etc., a coating of closely-defined colour and high lustre is required which has considerable corrosion and abrasion resistance. The volume of solution used is kept to a minimum for economic reasons and rapidly deteriorates, so that accurate control is difficult. Experiments on this subject, directed to producing a bright, acid-test resistant coating, are in hand and, in view of the lack of satisfactory advance by changes in chemical composition, attention is chiefly being directed to the electrical conditions, notably by use of pulsating current. It has been found possible to produce bright deposits of any thickness in this way from a solution at room temperature, and in addition to arrange the composition of solution and electrical current so that any coloured gold deposit from red to green can be obtained by adjusting a knob. This process appears to be of general applicability to electrodeposition of alloys.

An imported watch bracelet was examined and found to have a gold alloy layer (88% gold) 0·0008 in. (= 20 microns) thick, in accordance with a mark "20 microns." The coating was relatively hard (VPN 285) but was undoubtedly electroplated and subsequently polished. Electrogilt articles are subject to a lower rate of purchase tax than rolled gold articles and when electrogilt to the observed thickness are probably superior.

Anodised Aluminium Badges.—The Ministry of Supply asked the help of the Centre on the soldering of clips or lugs to army cap and collar badges made from super-purity aluminium and subsequently electro-polished, anodised and (in some cases) dyed gilt. A complete scheme of assembly, fluxing and furnace brazing was worked out and was accepted, but still had the serious

disadvantage of fully annealing the work-hardened super-purity aluminium and producing an impossibly weak badge. For this reason, experiments have been made in collaboration with The General Electric Company on cold pressure welding of the lugs. These have proved outstandingly successful in combining a simple method of joining with complete retention or even enhancement of the work-hardness conferred by stamping.

Colour of Metals.—The colour and reflectivity of jewellery and silverware metals is obviously of great importance from a sales and design point of view, but its appreciation tends to be confused by the reflection of surrounding coloured objects. Preliminary studies of this subject have been made with a spectrophotometer which measures the ratio of the reflectivity of a standard, such as E.P.N.S., and the specimen under test for each of nine different coloured lights, obtained by passing light from a tungsten lamp through appropriate filters. Nine points are thus obtained on a spectral reflectivity curve for the specimen. This is less satisfactory than a prism and slit spectrophotometer, but is probably reliable for the smooth spectral curves given by metals. From these curves the trichromatic coefficients and luminances (or average reflectivity) can be calculated and plotted on a colour triangle. Results have been obtained for a number of near-white metals and electroplated coatings, also for copper, brass and a series of gold alloys. It is believed that this work, whilst not immediately applicable to industry, can yield useful information on the simulation of precious metals by less expensive ones.

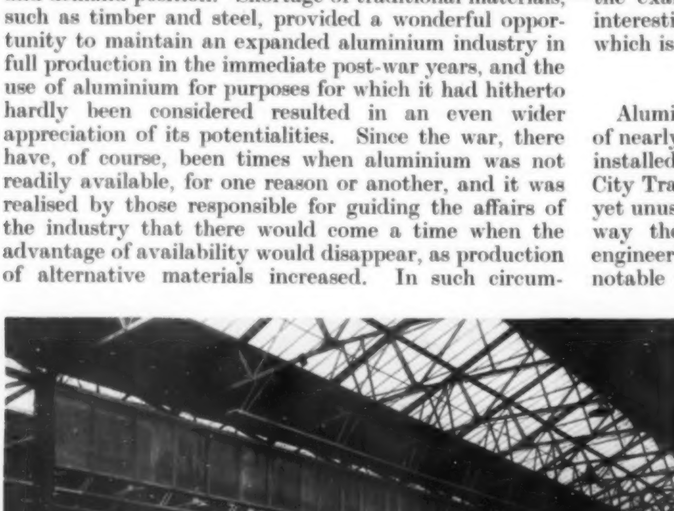
Engineering Uses of Aluminium Alloys

Some Recent Interesting Examples

THE progress of the aluminium industry since the war has been one of fluctuating fortune, as such factors as availability of currency for the purchase of dollar raw materials, the needs of an expanded aircraft building programme, and increased civilian requirements have each had their effect on the supply and demand position. Shortage of traditional materials, such as timber and steel, provided a wonderful opportunity to maintain an expanded aluminium industry in full production in the immediate post-war years, and the use of aluminium for purposes for which it had hitherto hardly been considered resulted in an even wider appreciation of its potentialities. Since the war, there have, of course, been times when aluminium was not readily available, for one reason or another, and it was realised by those responsible for guiding the affairs of the industry that there would come a time when the advantage of availability would disappear, as production of alternative materials increased. In such circumstances, the light alloys would meet increasing competition, and continuous efforts have been made to develop to the full those applications where the inherent properties of aluminium and its alloys are most favourable to their adoption. Building, cable sheathing and transport are not new fields of application for light alloys, but in the examples described below there are a number of interesting features which serve to indicate the progress which is being made.

Aluminium Plate Girders

Aluminium plate girders, with a span of 67 ft., a depth of nearly 6 ft., and each weighing 2½ tons, are now being installed in the roof of one of the depots of Birmingham City Transport. Aluminium members of this size are as yet unusual, and provide a striking instance of the headway the light alloys are making in the structural engineering field. There have, of course, been some notable examples of aluminium construction in recent years, and it is likely that the near future will see an increasing proportion of structures designed in light alloy, particularly where self-weight is an important factor, as in long-span roofs and bridges.



Two of the 67 ft. span aluminium girders erected in a Birmingham City Transport Depot.

These girders, which were built by Samuel Butler & Sons, Ltd., of Stanningley, Leeds, are being used to enable the depot to be converted from tram to bus storage. The buses need a different parking arrangement from that of the trams, and more room to manoeuvre. This is being provided by removing alternate stanchions and fitting large-span roof girders. The use of aluminium for the girders ensures that the load on the remaining stanchions is increased as little as possible, while the problems of transport and handling such large members are also considerably eased, particularly that of erection in the limited head-room available.

Each girder is built up of plate in Noral 65SWP alloy and of extruded angle sections in Noral 51SWP alloy. These materials, supplied by Northern Aluminium Co., Ltd., are both of the heat-treated aluminium-

This close-up of one of the 67 ft. span aluminium girders shows its construction in detail.

magnesium-silicon type of alloy that is now widely used for general structural work of all kinds, combining a high resistance to atmospheric attack with a yield strength similar to that of structural steel. The highest design stress assumed was 4·94 tons/sq. in. in the compression flange; for Noral 65SWP plate, a typical compressive 0·1% proof stress is $17\frac{1}{2}$ tons/sq. in., so that there is a factor of over $3\frac{1}{2}$ before 'yield' in this case.

The web, which is 5 ft. 9 in. deep, is of $\frac{5}{16}$ in. plate stiffened on both sides by vertical unequal angles; the angles are 5 in. × 3 in. or 4 in. × 3 in. and are spaced, with some exceptions, 3 ft. 9 in. apart. There are six splices in the web, the connections being made with double cover plates. The tension flange comprises two 6 in. × 4 in. angles, with their shorter legs riveted to the web, and a 14 in. wide $\frac{5}{16}$ in. thick plate. The compression flange is similar, except that the plate is 20 in. wide, $\frac{3}{8}$ in. thick, and stabilised along its edges by 3 in. equal angles. Three splices were made in each flange by a cover plate on the main flange plate, by smaller unequal angles nesting in the attachment angles, and by cover plates on the outside of the stabilising angles at the edges of the top flange. Hot-driven mild steel rivets, $\frac{13}{16}$ in. diameter, were used throughout, the usual precaution of staggered riveting being observed during assembly to avoid local overheating of the aluminium alloy.

In addition to three 67 ft. girders, the complete conversion scheme requires two girders of similar construction with spans of about 50 ft. and a number of 23 ft. girders to form door lintels. Together, they provide a good example of the application of aluminium to heavy structural engineering.

Welded Tipper

With the continuing development of successful methods of welding aluminium, it is not surprising that this joining technique should be extending its use to fields where hitherto riveted or bolted joints have been exclusively used. An interesting illustration of the trend is provided by a welded aluminium tipping body which, in a year's service with the North Thames Gas Board, has convincingly demonstrated the advantages both of its aluminium structure and of its manner of construction.

Prior to being handed over to the Gas Board, the body had undergone a six-months trial, hauling sand and ballast with the fleet of a firm engaged on a large site-levelling contract. The tipper completed this trial successfully and the experience gained enabled a few detail improvements to be made, particularly to the rear corner post mountings. The body was subsequently lent to the North Thames Gas Board who fitted it to one of their own standard tipping chassis. Here it has been inspected at six-month intervals and now, after eighteen months, is found to be standing up remarkably well to particularly arduous conditions.

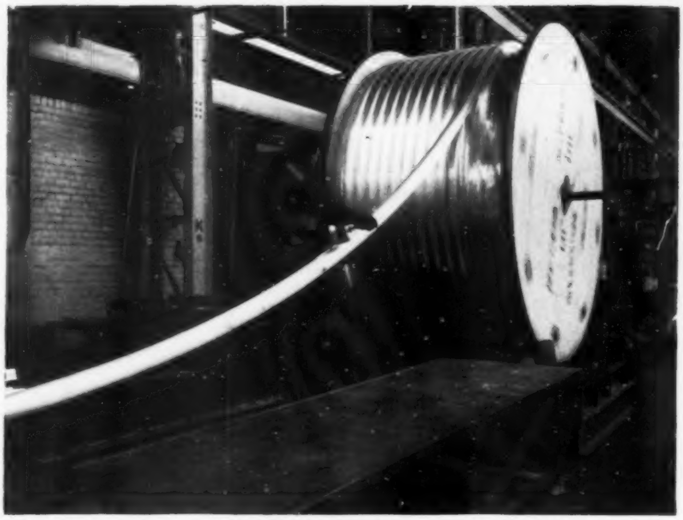
The loads carried are coke and breeze, the corrosive and abrasive nature of which causes such rapid deterioration of steel bodies that they require re-flooring at least once a year and are usually scrapped completely after three years. The aluminium body, however, is in excellent condition, and measurements confirm that there has been very little reduction in thickness of the metal in the sides and floor at points of maximum wear.

As the body had been assembled by operators with little previous experience of aluminium welding, a careful examination was made of the welds over the whole body. Only two cases of joint failure were found. These had occured at two points where large stresses were imposed when the truck was tipping on uneven ground, and in the more severe of these cases there was obvious evidence of the weld having been imperfectly made. In spite of the fact that some other welds bore similar signs, none of these had failed and the results are therefore felt to be very satisfactory.

North Thames Gas Board wagon fitted with welded aluminium tipping body.

The success of the aluminium body is attributable to its exceptional corrosion resistance, to which the use of welded construction makes an important contribution by eliminating riveted joints. This is because in adverse conditions the areas around the rivets are more liable to attack than other parts of a structure.

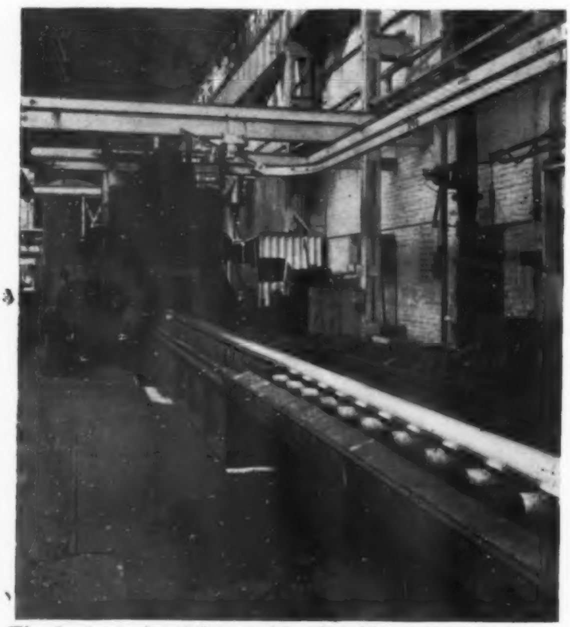
The tipper was a development undertaken by the constructors, Anthony Hoists, Ltd., in collaboration with Northern Aluminium Co., Ltd., who prepared the design and supplied the metal. Alloys with good welding characteristics and adequate strength were required: those selected were Noral M57S for the sheet and plate and Noral 51S for the extruded sections. Argonarc equipment was used for welding the joints, most of which were 4 to 6 in. long, although one continuous weld 6 ft. 6 in. in length was made in the construction of the floor, joining two pieces of 6 s.w.g. plate, each 6 ft. 6 in. long × 4 ft. wide. Sides and ends are of 10 s.w.g. plate stiffened with 3 in. × 2 in. × $\frac{3}{16}$ in. channel sections.



Coiling the $4\frac{1}{4}$ in. diameter cable sheathing tube straight from the extrusion press on to the drum.

Similar channels are also used for the crossbearers, which are connected at their ends by side raves of 4 in. × $2\frac{1}{2}$ in. × $\frac{3}{8}$ in. angle section. Corner posts at both front and rear are of 3 in. × 3 in. × $\frac{3}{8}$ in. angle and are carried below floor level where they are gussetted to the side raves and to the front and rear crossbearers. Fittings such as tailgate hinges and fastenings were machined from solid, but for further bodies cheaper steel fittings would probably be used.

This tipper, which is believed to be the first in this country of welded construction throughout, is a good example of the excellent results that can be achieved in aluminium welding by modern techniques, and is likely to be the forerunner of many other vehicles built by this means.



The largest aluminium cable sheathing tube ever made being extruded on the 8,000-ton Fielding press at Northern Aluminium Company's Rogerstone Works.

Biggest Aluminium Cable Sheathing Tube

The accompanying illustrations show the extrusion and coiling of a large aluminium tube that will be used to sheath a power transmission cable in Canada. Of $4\frac{1}{4}$ in. outside diameter, with wall thickness of 0·17 in., this is the largest aluminium cable sheathing tube ever produced, and it is supplied in 400 ft. lengths, unprecedented for a tube of this size. It is extruded by Northern Aluminium Co., Ltd., on their 8,000 ton Fielding press which, together with other presses in their Rogerstone Works, has already produced many thousands of feet of sheathing tube of $\frac{3}{8}$ in. diameter and upwards. As it emerges from the press, each length of the $4\frac{1}{4}$ in. tube is coiled on to a drum 12 ft. in diameter and 6 ft. wide, with a barrel of 10 ft. diameter. A drum of this size is necessary to allow the tube to be coiled without damage, and also to be successfully restraightened when it is eventually uncoiled.

Twenty lengths of the tubing have been ordered for sheathing a paper-insulated hollow segmental aluminium conductor that is to operate at 300,000 volts. This cable will carry current from the generators in the giant powerhouse built inside a mountain of the Coast Range near Kemano, British Columbia, to supply the smelter that Aluminium Company of Canada Ltd., are now building at Kitimat. The diameter of the conductor to be sheathed is $3\frac{1}{2}$ in. and that of the finished cable, after the tube has been sunk on to it, is about 3·85 in.

The press that produces the tube is the biggest in the country, perhaps the biggest actually in operation in the world (though several of still greater rating are planned in the U.S.A.). Built and installed by Fielding & Platt Ltd., of Gloucester, in 1942, it has produced some of the largest aluminium alloy extrusions ever made—most of them aircraft wing spar sections. The size of the billet container (20 in. diameter) made possible the production of the 400 ft. lengths of sheathing, the billets each weighing some 1,450 lbs.


HANNA

Illustration shows zinc sheets being produced at the London Zinc Mills Ltd.

NEWS AND ANNOUNCEMENTS

Capper Pass Awards

THE Capper Pass Awards, which are made annually from a sum of £200 placed each year at the disposal of the Councils of the Institution of Mining and Metallurgy and the Institute of Metals, by the Directors of Capper Pass & Son, Ltd., Bristol, are intended to encourage the publication of papers, in the *Transactions of the Institution of Mining and Metallurgy* and in the *Journal of the Institute of Metals*, on processes and plant used in extraction metallurgy, on the subject of assaying, and on processes and plant used in all branches of the non-ferrous metal industry. The Adjudicating Committee made the following awards for papers published in 1952 :

(i) Fifty Pounds to Mr. Edwin Davis, M.Sc., F.I.M., and Mr. S. G. Temple, M.Sc., A.I.M., for their paper on " Batch and Continuous Annealing of Copper and Copper Alloys " (*J. Inst. Metals*, 1952, **80**, 287–296).

(ii) Fifty pounds to Mr. C. P. Paton, B.Eng., for his paper on " Batch Thermal Treatment of Light Alloys " (*J. Inst. Metals*, 1952, **80**, 311–322).

(iii) Fifty Pounds to Mr. E. Ellwood, F.I.M., and Mr. T. A. Henderson, B.Sc., for their paper on " Some Exploratory Experiments on the Formation and Control of Magnetite During Copper Smelting Operations " (*Trans. Inst. Min. Met.*, 1952, **62**, 55–65).

(iv) Fifty pounds to Mr. P. M. J. Gray, B.Sc., A.R.S.M., for his paper on " The Production of Pure Cerium Metal by Electrolytic and Thermal Reduction Processes " (*Trans. Inst. Min. Met.*, 1952, **61**, 141–170).

(v) Twenty-five Pounds to Mr. E. A. Hontoir, B.Sc., A.I.M., for his paper on " Determination of Sulphur in Iron Pyrites " (*Trans. Inst. Min. Met.*, 1952, **62**, 95–107).

First Award of Foundry Fellowship

UNDER the terms of the Will of the late Robert Warner, a former Master of the Worshipful Company of Founders, the Company is charged with the administration of a fund for the purpose of creating Fellowships to foster research applied to foundry practice. The first award has been made to Mr. J. H. Gittus, B.Sc., a member of the research staff of the British Cast Iron Research Association. He will continue with his present work, and carry out a Fellowship programme on a part-time basis on the related subjects of mould erosion by the molten metal and the effect of mould condition on the surface finish of a casting. The work will be supervised by the Association's Research Manager, Mr. H. Morrogh.

Post-Graduate Physical Metallurgy

To meet the need of the metallurgical industries for more men with advanced scientific training, the University of Sheffield has established a Post-Graduate School in Physical Metallurgy. The courses will be planned to meet the needs of the students enrolled, and will normally be of one or two years' duration. In general, the first year course will be primarily for non-metallurgists, and lectures, together with courses of practical work, will provide a sound metallurgical background. The second year course is intended both for those who have completed the first year and for metallurgists returning from industry. As in the present session, the lectures will be supported by discussion groups and colloquia, and by experimental work. Experience has already shown the important part that can be played in advanced work by discussion among men of differing background. The topics to be dealt with in the next session, commencing in October, 1953, have now been chosen, and the advanced course will again be established on the block system, since the advantages of this have been so obvious this year. The session will be divided into five courses, each of five weeks' duration, as follows :—

October 5th–November 7th. Course I—Metallurgical Techniques.

November 9th–December 12th. Course II—Deformation of Metals.

January 11th–February 13th. Course III—Solidification of Metals.

February 15th–March 20th. Course IV—Physical Metallurgy of Heat Treatment.

April 26th–May 29th. Course V—Theory of Alloy Steels.

To succeed, the Post-Graduate School must be assured of a reasonable number of full-time students taking the full-session's course, but it may be possible, in addition, to accept a limited number of men for each of the five-week courses. Further particulars may be obtained from the Professor of Physical Metallurgy, The University, St. George's Square, Sheffield, 1.

Iron and Steel Board Appointments

SIR ARCHIBALD FORBES, chairman of the old pre-nationalisation Steel Board, is the independent chairman of the new Iron and Steel Board, which will supervise the denationalised industry. Sir Lincoln Evans is vice-chairman, and Mr. Robert Shone is the only other full-time member so far appointed. Sir Lincoln is to resign from his position as general secretary of the Iron and Steel Trades Confederation, and Mr. Shone is to terminate his directorship of the Iron and Steel Federation. In addition to the full-time members, the following appointments as part-time members of the new Board are announced : Sir Andrew McCance, joint managing director of Colvilles, Ltd. ; Mr. Neville Rollason, managing director of John Summers & Sons, Ltd. ; Mr. James Owen, general secretary of the National Union of Blastfurnacemen ; Mr. Andrew Naesmith, general secretary of the Amalgamated Weavers Association ; Mr. James Shaw, chairman of Allied Ironfounders, Ltd. ; Mr. Charles Connell, president of the Shipbuilding Conference ; Sir Percy Lister, chairman of R. A. Lister & Co., Ltd. ; and Mr. George Beharrell, managing director of the Dunlop Rubber Co., Ltd.

Instrument Exhibition

THE second British Instrument Industries Exhibition is to be held from Tuesday, June 30th to Saturday, July 11th, 1953, at the National Hall, Olympia.

The Exhibition has the active support of the trade associations of the industry and will cover all spheres of instrumentation in industry, medicine, research and education. In the industrial field, all classes of temperature, pressure and flow controllers will be displayed and there will also be complete equipment for navigation by

ai and sea and for land surveying. Almost every type of apparatus for the research laboratory in pure and applied science will be on show, together with British precision equipment in such diverse fields as meteorology and photography. The British photographic industry is to stage a representative display illustrating the part played by photography in education, industry, medicine and research.

Nickel Supplies

The International Nickel Company of Canada, Ltd., has signed a contract under which the United States Government has purchased for quick delivery a total of 120,000,000 lb. of metallic nickel and 100,000,000 lb. of electrolytic copper. Deliveries, which will start in December, are made feasible only as the result of an entirely new project in the Sudbury District of Ontario which permits additional production of 2,000,000 lb./month over I.N.C.O.'s current peak nickel production capacity.

The principal development is the recent completion of extended pilot plant studies of a process for the treatment of nickel-bearing pyrrhotite for the recovery of nickel and iron. This process, under continuous study and development for several years, involves removal from I.N.C.O.'s ores of a considerable portion of the iron content, which can be recovered as marketable iron ore. The Company will be proceeding immediately with plans for installation of plant for the carrying out of this latter operation.

I.N.C.O. already has at Sudbury the world's largest non-ferrous base metal underground mining operation. The nearing of completion of the Company's post-war underground mining development programme, in consequence of which it will be able to hoist shortly 13,000,000 tons of ore per year form underground, is likewise a decisive factor in the realisation of the project.

Deliveries under the new contract will not require diversion of nickel from that which is currently being supplied to the nickel trade from I.N.C.O.'s regular production. Indeed, by substantially increasing the nickel supply it can be expected that larger quantities of nickel should be available for all purposes.

Welding Research

The April issue of *Welding Research* includes a report on an examination of the tensile properties and oxy-acetylene welding characteristics of some aluminium-zinc-magnesium alloys, carried out by Dr. W. I. Pumphrey. The alloys examined were susceptible to heat treatment and should prove of value for applications where high strength and moderately good welding properties are required. The results obtained in gas welding tests made under restraint suggest that the presence of copper in aluminium-zinc-magnesium alloys markedly impairs their resistance to cracking during welding, and it would seem desirable to maintain the copper content as low as possible in aluminium-zinc-magnesium alloys to be fabricated by welding.

In the August, 1952, issue of *Welding Research*, a short introduction was given to a new approach which had been made to the subject of notch brittle fracture by Dr. A. A. Wells. It has now been possible to publish a full account of the work which has been carried out up to December of last year.

Personal News

High Duty Alloys, Ltd., announce the appointment to the Board of Mr. W. Scott-Warner and Mr. G. W. Richards. Mr. Warner joined the staff as Assistant Chief Accountant in 1940, being appointed Company Secretary in 1946—a position he will retain in his new appointment. Mr. Richards, who joined the Company in 1929 as Laboratory Assistant, has been concerned mainly with the production side of the forging plant, but was transferred to the Company's Redditch Works when production commenced in 1939, promoted Assistant Works Manager in 1941, Works Manager in 1943, and Manager of the Forgings Division in 1948.

At the Annual General Meeting of the Liverpool Engineering Society, Mr. Vernon L. Farthing was inducted into the Presidential Chair. As a Past President of the Liverpool Metallurgical Society, Mr. Farthing was recently elected the first Honorary Vice-President of the Society.

Spencer-Bonecourt, Ltd., announce that Mr. W. Hawkins has retired after 33 years service with the Company. Mr. Hawkins, who was well-known throughout the gas and steel industries, held the position of Chief Erection and Service Engineer. Mr. B. D. Clark has been appointed to succeed Mr. Hawkins.

Metropolitan-Vickers Electrical Export Co., Ltd., announces the following appointments, which took place from April 1st, 1953. Mr. F. C. Hallawell is appointed Manager for Brazil in succession to Mr. H. W. Foy, who continues in an advisory capacity. Mr. E. E. Sarasa is appointed Manager for Argentina. Mr. R. Morris is appointed Technical Representative in Colombia, Peru and Venezuela.

Lord Baillieu, Chairman of the Central Mining and Investment Corporation and of Dunlop, has been elected an Honorary Member of the Institution of Mining and Metallurgy in recognition of his services to the mining and metallurgical industries and as Chairman of the Empire Council of Mining and Metallurgical Institutions.

Sheepbridge Engineering, Ltd., announce the appointment of Mr. R. E. Dawtrey as Chief Engineer. Mr. Dawtrey will be responsible for all metallurgical, chemical and engineering research and development.

Mr. N. A. Jenkinson has been appointed London Manager of the Crane Department of Babcock & Wilcox, Ltd., upon the retirement of Mr. A. Merry. A member of the Executive Committee of the Mechanical Handling Engineers Association, Mr. Jenkinson has been associated with the crane and conveyor manufacturing activities of Babcock & Wilcox, Ltd., for the last fourteen years.

Metro-Cutanit, Ltd., announce that Mr. M. Littmann has resigned his Directorship. Dr. P. Schwarzkopf has been elected to the Board and Major J. W. Buckley has become Managing Director.

Dr. J. T. Stock, Vice-Principal and Head of the Chemistry and Biology Department of the Norword Technical College, has been awarded the Robert Blair Fellowship for 1953. Dr. Stock intends to spend a year in the Division of Analytical Chemistry at the Institute of Technology, University of Minnesota, U.S.A., working with Prof. I. M. Kolthoff.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

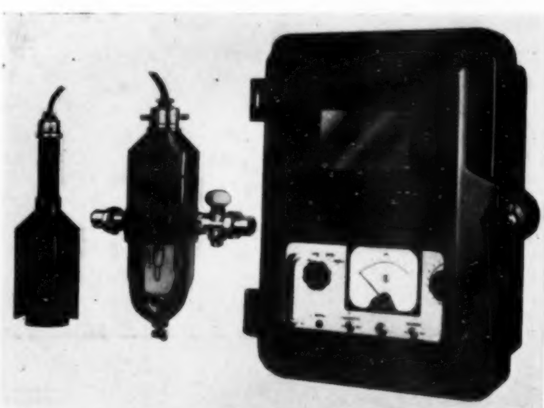
Industrial *p*H Meter and Electrodes

THE Model 28 Industrial *p*H Meter made by Electronic Instruments, Ltd. has been developed specifically for factory use and the design of the instrument and the electrode systems is the outcome of many years of practical application in the measurement and control of *p*H in industry. This instrument may be used by itself or it may be linked with standard recorders and controllers of the type used for the measurement of temperature, pressure and liquid level.

Electrically, the Model 28 *p*H Meter sets a high standard of performance, as it will run for several days with a stability of $\pm 0 \cdot 02$ *p*H without routine attention. An important feature is the provision of complete temperature compensation which enables the electrodes to be standardised at one temperature and to operate precisely at all other temperatures without readjustment of the controls. The instrument—which is designed for wall or panel mounting—is hermetically sealed and may, therefore, be installed in the open or in an atmosphere containing noxious fumes or vapours. Provision is made for pressurising, and a flameproof case can be supplied for use under exceptionally hazardous conditions.

General experience in the *p*H field has shown that insufficient attention has been paid in the past to the design of industrial electrode systems; the continuous flow and dip type electrode systems which accompany the Model 28 are scientifically engineered to ensure that replacement of electrodes can be carried out with the minimum of trouble and with the assurance that the high insulation required in the electrode head will not be impaired in the process.

Two significant developments in electrodes are announced by the firm. The first is the production of a high-temperature electrode consisting of a highly complex glass as the *p*H responsive membrane, together with a unique arrangement for stabilising the internal elements of the electrode. These electrodes may be used over the whole *p*H range, and as the glass contains no sodium, continuous operation at 100° C. and in strongly alkaline solutions is possible.



The second improvement is the provision of a sealed reference electrode which does not require regular replenishment of the potassium chloride solution. This electrode was designed after thorough study of the origin of spurious potentials which often arise in the measurement of liquids of low electrolyte content, and such errors are now satisfactorily eliminated. The sealed reference electrode may be used under vacuum, or at pressures up to 50 lb./sq. in., at room temperatures, or at 100° C. Under favourable circumstances, one year's service may be expected, after which the electrode can be returned for replenishment.

Electronic Instruments, Ltd., Red Lion Street, Richmond, Surrey.

New Murex Welding Electrodes

FIVE new electrodes for electric arc welding are announced by Murex Welding Processes, Ltd. They are the Speedex, Deepex, Ferex B, Contex and Cinnifex, and all have successfully undergone extensive field trials and have been in use in industry for some time, but in limited quantities mainly owing to the steel shortage. Now that increased steel supplies are available, the new electrodes are going into full scale production and they are briefly described in the following details.

Speedex.—This is a new mild-steel electrode designed to facilitate very high-speed manual arc welding under normal operating conditions and with normal penetration. Another special feature of this rod is that the slag is of the inflated type and is exceptionally easy to remove, thus enabling further time to be saved on welded work. The electrode is suitable for making downhand butt and fillet welds, and horizontal-vertical fillet welds. Speedex is an ideal electrode for welding the decks of ships and tank tops, or for the prefabrication of bulkheads and other items in the downhand position. The radiographic quality of the weld metal is of a high commercial standard and the surface of the weld deposit is extremely smooth with freedom from undercut at the edges.

Deepex.—This new deep penetration electrode has been specially designed to produce butt welds in the downhand position in mild steel plate of thicknesses up to ½ in., without edge preparation. Thicker material can be welded by the adoption of partial preparation. Considerable economies can, therefore, be made in preparation work when using this electrode, and neat sound welds can be made in a wide range of plate thicknesses.

Ferex B.—This is a low-hydrogen type of electrode suitable for the welding of medium alloy steels and mild steel. The electrode is specially designed to produce welds of high impact value at sub-zero temperatures, and to resist cracking in welds made under conditions of restraint. Many of the low and medium alloy steels, which are not weldable with ordinary mild steel electrodes, unless a considerable pre-heat is employed, can

be welded with this electrode at room temperature or with a only slight pre-heat.

Contex.—This electrode has been designed primarily for the welding of downhand and overhead joints in mild and low alloy high tensile steels by using the "touch welding" technique, thus simplifying the production of neat and uniform weld deposits. It is also suitable for vertical up welding providing a short arc length is maintained. The slag is of the self-releasing type and there is a minimum of spatter and undercut. A feature of the Contex is that long runs on thin gauge material can be obtained from relatively large electrodes.

Cinnifex.—A new type of electrode for welding cast iron, produced essentially for the welding of nodular and other types of cast iron with high ductility. The deposit gives an analysis of 55% nickel and 45% iron. The electrode is also suitable for welding ordinary cast iron where strength is required.

Murex Welding Processes, Ltd., Waltham Cross, Herts.

Automatic Welder for Building Up

The use of automatic welding equipment for re-building and hard-surfacing components has increased considerably during recent years and a new general purpose welding machine tool for this type of work has been designed and manufactured by Fusarc, Ltd.

The equipment is in the form of a lathe, above which is mounted a welding head on a traversable carriage, a 30-in. diameter tilting turntable is used as a headstock. With the headstock in the tilted position the machine can handle tapered work, rebuild flanges or normal fillet work; in the vertical position, and in conjunction with a spring-loaded tailstock, worn shafts can be built up. During shaft rebuilding, the welding head carriage traverse motion is linked with the headstock drive, so that the weld deposit is in the form of a helix. The welding head can also be traversed at normal welding speeds for longitudinal welding, the length of the machine bed being 8 ft.

Either Fusarc or Unionmelt welding heads can be fitted to the machine, and a comprehensive range of patented continuous electrodes is available for use with either process for rebuilding or resurfacing applications.

Fusarc, Ltd., Team Valley, Gateshead, Co. Durham.

Gas Ballast Pumps

Mechanical high vacuum pumps which will pump condensible vapours, such as water vapour, without oil contamination or loss of pumping capacity are the result of joint efforts of National Research Corporation, of Cambridge (Massachusetts) and E. Leybold's Nachfolger, of Cologne (Germany), the world's oldest manufacturer of vacuum equipment. National Research Corporation imports the basic pump units, and is adding American motors, pulleys, flanges and controls.

The N.R.C. Gas Ballast Pump prevents the condensation of vapours by keeping their vapour pressures below their condensation pressures. This is achieved by the use of gas ballast, a small quantity of air being bled into the pump after intake has been completed and as compression is about to occur. The power requirements are as low as, or lower than, those for conventional mechanical pumps lacking the gas ballast feature.

These pumps are available in single stage units with capacities ranging from 2 to 400 cu. ft./min., compound

units (i.e. two motors on same shaft) with capacities from 2 to 15 cu. ft./min., and in combination units (in which two single-stage pumps are combined in series) with capacities from 30 to 400 cu. ft./min.

National Research Corporation, Seventy Memorial Drive, Cambridge, Massachusetts, U.S.A.

Welding Electrode Comparator

Originally produced for its members, a comparator for mild steel metal-arc welding electrodes developed by the British Welding Research Association is now on sale at a price of 5s. The comparator takes the form of a slide rule and has been generally acclaimed for the ready-to-hand method by which it enables welders, designers and others to obtain the basic characteristics of the electrodes, as specified by the makers, in accordance with B.S.1719. On the front of the rule appears the essential information on the coating, position, current and voltage for given electrode groups, together with the nearest American equivalent, whilst on the reverse side are shown the particular electrodes and manufacturers name. Helpful explanatory notes are issued with the comparator.

Publications Department, British Welding Research Association, 29, Park Crescent, London, W.1.

CURRENT LITERATURE

Book Reviews

PHYSICAL CONSTANTS OF SOME COMMERCIAL STEELS AT ELEVATED TEMPERATURES

Edited by the British Iron and Steel Research Association. X + 38 pp. 31 tables, 43 graphs. London, 1953. Butterworth Scientific Publications, 21s. (postage 8d.).

In this book values of specific heat, coefficient of thermal expansion, electrical resistivity, thermal conductivity and derived data are tabulated for 22 commercial steels over the temperature range 0° C. to 1,200° C. at intervals of 50° C. In addition to the tables, total heat/temperature and expansion/temperature curves are given for most of the steels over a temperature range which includes the transformation region. Information on some additional steels is given in an Appendix. The work is based on determinations made by the National Physical Laboratory which were originally reported in papers to the Iron and Steel Institute in 1939 and 1946.

To those concerned with problems of heat conduction in steels these two papers have long been the chief source of information on physical constants. The appearance of this book, which presents the information in unified and more convenient form, is thus most welcome. The tables are well laid-out and easy to read and a clear distinction is made between experimental and deduced values. It should perhaps have been more clearly emphasized that the expansion/temperature curves in the neighbourhood of the transformation region apply to heating only, and strictly speaking only to the heating rate (3 to 4° C. per minute) at which they were determined. Some mention might also have been made of the methods outlined in the original papers for estimating certain of the physical constants of steels from their composition. These methods are sometimes very useful. The only major criticism, however, concerns the binding, which is unworthy of what will undoubtedly be a standard work of reference.

M. B. Coyle

PERMANENT MAGNETS

58 pp., numerous graphs and illustrations. Sheffield, 1953. The Permanent Magnet Association. 10s.

The Permanent Magnet Association and its member firms have played a conspicuous part in the development of new magnetic materials of ever increasing properties. They were the first to produce the now universally known magnet material, Alnico, and also developed the original anisotropic alloys which led to the introduction of Alcomax and all other uni-directional magnets. A more recent achievement was the production of the niobium-bearing alloys, Alcomax III and IV, two of the most efficient commercially available permanent magnet materials at the present time. At the Physical Society's Exhibition, 1950, the P.M.A. first displayed columnar crystal magnets now marketed under the name of Columax. These magnets are cast in such a way that columnar crystals are developed with the same orientation as the preferred axis of magnetisation. The method of production of this material restricts it to simple shapes and it has, therefore, only a limited field of application, although within that field it exhibits considerably enhanced properties as compared with Alcomax III.

Enough has been said to indicate the authority with which the Association and its members speak on the subject of permanent magnets, and it is appropriate that this book should have been written with the same degree of co-operation as that which has characterised the development work. The express purpose of the book is to provide authoritative information on the subject of permanent magnets, and following a brief outline of the domain theory of magnetism, the various factors affecting the design of magnets are considered. Permanent magnets are made from a wide range of materials which fall into two main groups—those which are isotropic, and those which are anisotropic, the latter exhibiting enhanced magnetic properties along one axis. Besides magnetic properties, however, considerations of machinability and other mechanical features may enter into the choice of the most suitable material, and information on such matters is given along with the magnetic properites of commercial materials, including the new Columax.

Further sections of the book deal with the best magnetisation practice, and with the methods adopted for checking the characteristics of the finished magnets. The properties of a permanent magnet may be impaired by heating, mechanical shock and electrical fields, and details are given illustrating the extent of these effects. A well-illustrated final section deals with a few of the many applications of permanent magnets and shows typical methods by which they are incorporated in apparatus.

Trade Publications

The first edition of Part I of " Noral Sheet Products " has recently been issued by Northern Aluminium Co., Ltd., Banbury. Part I deals with flat sheet, coiled sheet and plate, and together with Part II this information supersedes that given in Section III of the Noral Handbook. It is intended as a ready guide to the dimensions of sheet and plate products of the company, and of the degree of accuracy with which these are normally made. Details are given of the alloys available and the standard specifications which they meet.

It is more than 50 years since the late Dr. Ferranti laid down a small foundry for the production of high quality castings for use in Ferranti products. Since that time, the Ferranti foundry has gradually increased its capacity and has taken a leading part in foundry developments, including the introduction of special high-resistance non-magnetic cast irons. In a handsome, illustrated booklet, particulars are given of the types of iron castings produced, together with a description of the foundry and its equipment.

Technical data on the Kynal and Kynalcore range of aluminium alloys, made by I.C.I. Metals Division, are provided in convenient tabular form in a recently issued publication. The information provided includes the I.C.I. classifications and complementary specifications, together with the mechanical properties and the

composition of the alloys concerned. In order to assist designers and engineers to select the alloys most suited to their requirements, the materials are also classified according to durability, strength at high temperatures and suitability for severe cold forming, machining, welding and anodising. Of particular interest is a section giving the physical properties of pure aluminium in comparison with other metals.

DURING recent years, synthetic resin core-binders have gained considerable ground, as in many respects they give a better performance than conventional oil-binders. They have, however, been long in gaining general acceptance, since they have been found to suffer from stickiness in use and very rapid evaporation, and are subject to excessive frictional heat during mixing. To meet the demand for a binder free from the disadvantages which have militated against their wider use, Aero Research, Ltd., Duxford, Cambridge, have introduced "Resolite" 400, a urea-formaldehyde synthetic resin binder, supplied in the form of a paste or cream, which is described in a newly published leaflet.

THE greater accuracy now demanded by most heating processes calls for a clean easily-regulated fuel, and in districts where town's gas is not available, or is too expensive, clean producer gas is the best alternative. Where coke or anthracite fuels are gasified, gas cleaning is well established, but hitherto gas cleaning plants for bituminous coal have suffered from producing as a by-product wet emulsified tar, difficult to sell or burn. A new design of cleaning plant developed in France after World War II is described in a new pamphlet issued by Gibbons Heurtey, Ltd., Dibdale, Dudley. This plant, which is applicable to producers with a gas outlet temperature of under 620° C., gives a very clean gas and recovers the by-products as water-free pitch and oil.

IN a new edition of "Hardfacing with Deloro Stellite," issued by Deloro Stellite, Ltd., Shirley, Birmingham, a considerable amount of information has been added to enable the welder or planning engineer to hardface satisfactorily alloy and special steels. Full details of the pre-heat and subsequent cooling necessary for the oxy-acetylene and arc depositing of Stellite on the B.S.En. series of steels are given in tabular form. As the analysis of the En. steels is also given, these tables are a valuable guide to the hardfacing heat treatment of most steels encountered in industry. The arc deposition of Stellite rods is covered in detail, and mention is made of the opportunities the firm gives for training operators in hardfacing at its school in Birmingham.

THE vertical "hairpin" furnaces dealt with in Wild-Barfield Catalogue V.H.453 have a proved performance over many years. Two standard models are available, one having solid rod "hairpin" shaped elements giving a maximum operating temperature of 1,050° C., and the other with tubular "hairpin" elements and a maximum temperature of 1,150° C. Each model is supplied in six sizes, with working chambers ranging from 12 in. diameter × 32 in. depth to 36 in. diameter × 56 in. depth. This type of furnace is suitable for hardening, annealing, normalising, carburising, etc.

A NEW Incandescent Heat Company publication deals with the A.G.M. automatic gas machine. This is a completely automatic and highly efficient gas producer, designed to generate hot gas of high and constant quality from solid fuels such as bituminous coal, anthracite or coke. It is intended for the firing of industrial furnaces at all working temperatures, the gas being delivered straight from the adjacent A.G.M. to the furnace, without any loss of sensible heat. The machine has a self-regulating fuel feed, synchronised with demand ; an automatic self-regulating vapouriser, for preventing the adhesion of ash to the producer walls ; continuous mechanical agitation of the fuel bed ; and thermostatically controlled ash discharge.

WE have received from the Metals Division of Imperial Chemical Industries, Ltd., a new booklet on Kynal solders and flux for aluminium. The difficulties encountered in soldering aluminium are well-known and it is only by a thorough understanding of general soldering practice, of the best joint design, of those aluminium alloys which are suitable for soldering, and of the effects of service conditions on the life of soldered joints, that the method can be successfully applied. I.C.I. Metals Division has studied the problems involved and general information on the subject is given in the booklet, based on experience gained in the development of solders and fluxes.

A NEW Autolec Thermal Storage Systems catalogue has been issued by G.W.B. Electric Furnaces, Ltd., giving details of the latest equipment for space heating by electrode water heaters in conjunction with a thermal storage system. Such a system offers the advantages of Automatic control, cleanliness and high efficiency, whilst at the same time allowing power to be taken from the supply system during off-peak periods. It also has the advantage over solid-fuel-fired boilers for space heating, in that no attendant labour is required. Copies may be obtained from Dibdale Works, Dudley.

A LEAFLET recently issued by Croda, Ltd., Goole, Yorks., deals with Metox red oxide metal priming paint. This paint leaves a flat finish, and is based on an oleo-resinous medium and pigmented with red iron oxide and zinc chromate. These together form a film with high anti-corrosive and rust-inhibitive properties. Metox is quick drying, being surface dry in two hours and handle-proof in four hours.

Books Received

"Metal Data" (Revised Edition of Metals and Alloys Data Book). By Samuel L. Hoyt. 526 pp. inc. index. New York, 1952. Reinhold Publishing Corporation. In this country through Chapman & Hall, Ltd. 80s. net.

"Physical Chemistry of Metals." By Lawence S. Darken, Ph.D. and Robert W. Gurry, Ph.D. With a Collection of Problems by Michael B. Bever, Ph.D. Metallurgy and Metallurgical Engineering Series. 535 pp. inc. index. New York, Toronto and London, 1953. MacGraw-Hill Book Company, Inc. 61s.

"Technology of Engineering Materials." By B. Richard Hilton. 389 pp. inc. glossary, index and numerous illustrations. London, 1953. Butterworths Scientific Publications. 36s. By post 1s. 6d. extra.

"High-Temperature Alloys." By Claude L. Clark. Pitman Metallurgy Series. 383 pp. inc. index, tables and numerous illustrations. London, 1953. Sir Isaac Pitman & Sons, Ltd. 60s. net.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
JUNE, 1953 Vol. XLVII, No. 284

Standard Refractory Tubes in Recrystallised Alumina, Mullite and Aluminous Porcelain

The manufacturers of special refractories, with the assistance of the Sintered Oxides Sub-Committee of the Inter-Service Metallurgical Research Council (Ministry of Supply and Admiralty), have added to the list of tubes of standard dimensions published in 1950. The revised standard sizes are listed, together with an explanation of the system of tolerances, and additional matter that may facilitate manufacturer/consumer co-operation.

A RAPID increase in the demand for tubes of alumina, " mullite," and " aluminous porcelain," led to some standardisation of dimensions in 1950 by the manufacturers with the assistance of the Sintered Oxides Sub-Committee of the Inter-Service Metallurgical Research Council (Ministry of Supply and Admiralty). Later experience has resulted in review and extension of these standards, which in their revised form are listed in the tables. All dimensions are expressed in millimeters, and the manufacturers have agreed to adopt this form of measurement as standard for the future.

Tolerances

The adopted tolerances indicate the appreciably greater limitations in the manufacture of recrystallised alumina as compared with mullite and aluminous porcelain. It will be observed that tolerances have not been specified with regard to length. This is because the tubes are cut after manufacture, and the accuracy is usually more than sufficient. Two main considerations usually determine other geometrical requirements :—

(1) the user needs a tube of such bore that a given object will pass through it, or can be manipulated within it ; and
(2) parts or all of the exterior must pass through one or more cylindrical apertures.

These requirements may determine not only the nominal bore and outer diameter, but the straightness and circularity. It may be noted that whereas variations in average bores and external diameters are mainly determined by the technique of producing and firing the tubes, deviations from straightness and circularity can occur in tubes of correct average dimensions, and it is not easy to ensure that the deviations are always small enough to be unimportant. If all tubes were straight and circular, the specifications of average bores and external diameters would involve the user in no difficulty, for he would merely have to be guided by his known requirements and the tolerances stated by the manufacturers. Unfortunately, variations in straightness and circularity can be infinite in their diversity, although appreciable variations of this nature more usually apply only to recrystallised alumina. In such cases they can be simply expressed only by arbitrary selection which may not correspond with the precise needs of the user. For example, lack of straightness is expressed in the tables as the greatest gap between the tube and a plane on which it is rolled, divided by the length of the tube, this ratio being expressed as a percentage. This simple and convenient criterion has been used for all tubes except those designed as insulators for thermocouples. Reference to Tables II and III shows that in the case of an insulator, whether of circular or of oval section, there has been specified the bore of a tube gauge which can contain the whole insulator. It should be noted that the use of short insulating tubes sometimes enables a narrower outer tube to be used than would otherwise be possible. The minimum bores of both single and twin bore insulators are also specified as indications of the sizes of wire which may be used.

General

It is believed that the dimensional system adopted will usually reduce the task of choosing suitable tubes to little more than reading the standard tables. Thus, for tubes other than insulators, the maximum external diameter is an indication of the least diameter of a short cylindrical hole through which the tube could be expected to pass. If, to this diameter, we add the maximum deviation from straightness, calculated from the actual length of the tube, we obtain the least diameter of a true cylindrical tube which can be expected with certainty to contain completely the listed tube. As an illustration, let us consider a tube 600 mm. long, and in other respects as stated in the first entry in Table IV for pyrometric and furnace tubes in recrystallised alumina. The maximum deviation from straightness is less than 1% of 600 mm., that is, less than 6 mm. The maximum external diameter is 9 mm. so that the smallest cylindrical enclosure which we could be certain would contain the *whole* tube, would have a diameter slightly in excess of 15 mm. It will be appreciated that the occasions when this is essential are relatively few. The bore is 5·0 mm. ± 10%, so that the smallest possible bore is 4·5 mm. Hence, the smallest twin bore insulators listed, even in 75 mm. lengths, would generally fit the tube, although there might be cases in which a

TABLE I.—SMALL SINGLE BORE TUBES (OPEN BOTH ENDS) IN RECRYSTALLISED ALUMINA, ALUMINOUS PORCELAIN AND MULLITE.

Bore mm.	Tolerance Limits %	Nominal Wall mm.	Maximum Ext. Dia. mm.	Normal Maximum Lengths	
				Recrystallised Alumina and Mullite mm.	Aluminous Porcelain mm.
1·0	±20	1·0	3·6	300	450
2·0	±15	1·25	5·3	450	600
3·2	±12·5	1·25	6·5	600	750

Other Lengths and Sizes and Tubes with one Closed End.—Subject to special inquiry.
Straightness.—Maximum deviation from straightness: 1·0% of the length for Recrystallised Alumina, and ½% of the length for Aluminous Porcelain and Mullite.
Maximum Diameter.—Covers all tolerances including ovalness.

TABLE II.—SINGLE BORE INSULATORS, 25, 50 AND 75 MM. LENGTHS IN RECRYSTALLISED ALUMINA, ALUMINOUS PORCELAIN AND MULLITE.

Minimum Bore mm.	Nominal Ext. Dia. mm.	Bore of External Tube Gauges for Lengths		
		25 mm.	50 mm.	75 mm.
0·65	2·0	2·6	2·75	3·0
0·9	2·6	3·1	3·25	3·5
1·3	3·5	4·0	4·15	4·4

Other Lengths and Sizes.—Subject to special inquiry.

TABLE III.—TWIN BORE INSULATORS, 25, 50 AND 75 MM. LENGTHS IN RECRYSTALLISED ALUMINA, ALUMINOUS PORCELAIN AND MULLITE.

Minimum Bore mm.	Circular Nominal Ext. Dia. mm.	Oval Nominal Ext. Sizes mm.	Bore of External Tube Gauges for Lengths		
			25 mm.	50 mm.	75 mm.
0·65	3·0	3 × 2	3·6	3·75	4·0
0·9	4·0	4 × 2·6	4·6	4·75	5·0
1·3	4·8	4·8 × 3·0	5·4	5·6	5·8
1·9	7·5	7·5 × 4·75	8·3	8·5	8·75

Other Lengths and Sizes.—Subject to special inquiry.

larger outer tube would be needed. This is because, although the list shows apparently ½ mm. clearance for the longest twin bore insulator, clearance may be lost by lack of straightness of the outer tube. This example illustrates both the utility and the limitations of the system. The limitations are not serious, and are outweighed by the accompanying simplicity.

Special lengths and sections, and tolerances smaller than those listed, will be subject to special quotations, which normally will involve higher prices and longer times of delivery than those of standard ware. It is in the interest of both consumers and manufacturers that such requirements be kept to a minimum. Quite a small alteration in existing apparatus will often enable standard ware to be used, and when new apparatus is designed, adjustments should be provided in accordance with the known tolerances. Further, ease of manipulation is often more important than first cost, for both time and material may be wasted when objects are manipulated within tubes which fit too closely.

Conditions of Use

The choice of a refractory tube involves consideration of the nature of the refractory, and of the conditions of use. The manufacturers will gladly advise on these products if given adequate information. Some users may have special problems, but most cases are covered by answers to the following questions.

(1) What is the *true* maximum temperature expected?
(2) What will be the period of the firing cycle, and the approximate distribution of temperature along the tube?
(3) In the case of a horizontal tube, what will be the length of the hot section, and how will it be supported?
(4) What solids, liquids, and gases, will be in contact with the hottest parts of the tube, both inside and outside?
(5) What will be the pressure of such gases? In the case of a vacuum, will continuous pumping be permitted?
(6) In the case of an electric resistance furnace, will the current be direct or alternating? What type of metal will be used for the winding?

TABLE IV.—PYROMETER AND FURNACE TUBES (OPEN, OR CLOSED ONE END) IN RECRYSTALLISED ALUMINA.

Bore mm.	Tolerance Limits %	Nominal Wall mm.	Maximum Ext. Dia. mm.
5·0	±10	1·5	9·0
5·75	±10	1·5	9·8
6·25	±10	1·85	11·2
8·0	±10	2·0	13·5
10·0	±10	2·25	16·0
12·5	± 8	2·5	19·0
15·5	± 8	2·75	23·0
19·5	± 8	3·0	28·0
22·5	± 8	3·0	31·5
25·5	± 6	3·25	34·0
28·5	± 6	3·5	38·0
32·0	± 6	3·5	41·5
38·0	± 6	4·0	49·0
45·0	± 6	4·5	57·5
50·0	± 5	4·5	63·0
55·0	± 5	5·0	69·0
65·0	± 5	5·0	80·0

Lengths.—Normally supplied from 300 mm. in 75 mm. steps to 900 mm. long.
Other Lengths and Sizes.—Subject to special inquiry.
Straightness.—Maximum deviation from straightness: 1% of length.
Maximum Diameter.—Covers all tolerances including ovalness.

TABLE V.—PYROMETER AND FURNACE TUBES (OPEN, OR CLOSED ONE END) IN ALUMINOUS PORCELAIN AND MULLITE.

Bore mm.	Tolerance Limits %	Nominal Wall mm.	Maximum Ext. Dia. mm.
5·0	±10	1·5	9·0
5·75	±10	1·5	9·8
6·25	±10	1·85	11·2
8·0	± 8	2·0	13·5
10·0	± 8	2·25	16·0
12·5	± 6	2·5	19·0
15·5	± 6	2·75	22·5
19·5	± 6	3·0	27·5
22·5	± 6	3·0	31·0
25·5	± 5	3·25	33·5
28·5	± 5	3·5	37·5
32·0	± 5	3·5	40·5
38·0	± 5	4·0	48·0
45·0	± 5	4·5	56·5
50·0	± 5	4·5	62·0
55·0	± 5	5·0	68·0
65·0	± 5	5·0	78·5

Lengths.—Normally supplied from 300 mm. in 75 mm. steps up to 1,350 mm. for bores up to 32 mm. diameter and up to 900 mm. for the larger bores.
Other Lengths and Sizes.—Subject to special inquiry.
Straightness.—Maximum deviation from straightness, ½% of the length.
Maximum Diameter.—Covers all tolerances including ovalness.

Automatic Machine Showroom

AT their Worcester factory, Heenan & Froude, Ltd., have completed a permanent showroom for the display of automatic metal-forming machines. This showroom, which has been built primarily for visitors to the United Kingdom, will house a full range of Heenan automatics, including a ring coiling machine, a fence stapling machine, a knotted chain machine, a paper clip machine, a chain making machine, a straightening and cutting machine, four nail presses, and a number of other wire- and strip-forming machines.

National Physical Laboratory Open Day

Techniques Featured in Items of Metallurgical Interest

THE Annual Open Day of the National Physical Laboratory at Teddington was held last month, and scientists and technologists from all over the country who attended had an opportunity of seeing the broad scope of the work covered by the Laboratory. Many changes have taken place since its foundation in 1900, and during the last year the Radio Division has become incorporated in the Radio Research Organisation, but its work is being continued for the time being at the Laboratory. A further organisational change has been the transfer of the High Temperature Mechanical Properties Section to the Metallurgy Division. This section is studying, in particular, creep and fatigue at elevated temperatures. Creep tests have been carried out in the temperature range 900–1,000° C. on some gas turbine materials, and equipment has been developed for creep testing at temperatures up to 1,400° C.

Almost 200 exhibits were on show, representing most of the activities of the Laboratory. Many of these were of metallurgical interest—and not all of them in the Metallurgy Division—but space precludes us from dealing briefly with more than a few in the following account.

Fatigue at Notches

Most fatigue failures in materials in service occur at stress concentrations such as a hole, a sharp radius or a surface scratch. Some materials show a greater tendency for such failures than others ; these are said to be more notch sensitive. It is considered that this sensitivity depends largely on whether the material is capable of deforming plastically at the stress concentration during dynamic stressing. If this is so, the maximum stresses will be relaxed and the likelihood of failure by fatigue will be reduced.

To investigate this, tests have been made on a mild steel. The plastic deformation occurring was determined from fatigue tests on plain unnotched testpieces by measuring both the dynamic stress and strain. Fatigue tests were then made on square section testpieces with transverse holes ; this form of notch was chosen because photoelastic data is available for the stress distribution. This shows that for a material deforming elastically the maximum stress occurs at the edge of the hole and is 2·3 times the average stress. When allowance is made for the plastic deformation occurring in the mild steel, this figure is reduced to 1·7, whereas the reduction in fatigue strength caused by the notch was shown by the tests to be 1·6. The comparatively high notched fatigue strength of mild steel may thus be attributed to plastic deformation. Harder materials show little or no plastic deformation, and consequently are more notch sensitive (though they become considerably less so with decrease of testpiece size).

Further tests are planned on materials at high temperatures, where the effect of plastic deformation will be more important.

Properties of Tilt Boundaries

The imperfection structures in metal crystals which have been observed microscopically cannot be directly related to the hypothetical crystal imperfections which figure in current physical theories of plastic deformation. However, one type of observable imperfection, the tilt boundary, which is formed by the slight mis-orientation of two adjoining regions of a crystal, can be simply related to theory. Thus the experimental behaviour of such boundaries is of interest.

It is found, in the case of metal crystals displaying good cleavage properties, for example zinc, that cleavage facets can be prepared showing individual tilt boundaries of high visibility even though they arise due to lattice mis-orientation of less than 1°. When such specimens, suitably cleaved for observation, are loaded so as to subject the tilt boundary to shear, it is observed that the boundary becomes mobile at shear stresses of the order known to cause glide in single crystals.

An apparatus has been constructed which allows the position of the tilt boundary to be continuously observed as the crystal in which it is located is deformed at creep rates of strain, or alternatively under conditions of cyclic stressing. The specimen can be heated and the rate of boundary movement measured over a range of temperature. For purposes of measurement, photographic recording is used. The surface tilt at any boundary is measured interferometrically and since the boundary is observed on a crystallographic cleavage plane, the position of its trace can be referred to the traces of known types of crystallographic markings. This is of use in investigating the equilibrium properties of systems of tilt boundaries, and also the surface markings associated with the movement of tilt boundaries through certain crystals.

Specialised Electron Microscopy Replica Technique

The electron microscope, with its magnification of up to 100,000 times, is one of the most powerful research tools now available and is being increasingly widely used in many fields, including that of metallurgical research. In this latter application, metal surfaces are studied by means of a plastic replica stripped from the surface, the replica being no more than a few millionths of an inch thick in order to permit the passage of electrons through it. Because of this replica technique and because the field of view at very high magnifications is correspondingly small, it has previously been found extremely difficult to identify in the electron microscope any particular predetermined area of the original specimen. This difficulty has now been overcome by the development of a method which is essentially simple and requires no precision apparatus.

The metal specimen surface is first examined under an optical microscope and a circle about an eighth of an inch in diameter is drawn around the chosen feature of interest. A replica from this surface is floated in a beaker of water and viewed under an optical microscope, the circle serving to indicate the approximate position of the chosen feature. The specimen grid which carries the replica in the electron microscope and which is a thin copper disc an eighth of an inch in diameter with about 200 holes to the inch is now positioned just under the

replica in the beaker. By various adjustments the feature of interest is made to lie over a particular hole near the centre of the grid, after which the grid and replica are lifted together from the water. In the electron microscope the centre of the grid is easily located and so the feature of interest nearby is identified. By this means the area chosen under the optical microscope may be examined, after successive mechanical or thermal treatments, at the superior magnification and resolution of the electron microscope.

Brittle Fracture in Iron

The crystalline appearance of fracture in mild steel when it breaks in the manner usually referred to as "brittle fracture" is caused by the fracture occurring across the cleavage plane of the individual crystals. An understanding of the mechanism of this type of failure obviously requires a knowledge of the cleavage strength of iron crystals. The most straightforward manner of determining this strength is by the use of single crystals so that no interference from grain boundaries will be experienced if the crystal is broken in tension. At ordinary temperatures a plain single crystal of iron cannot be broken along the cleavage plane by plain tension as the crystal yields by slip at a much lower stress than the cleavage strength. At lower temperatures (about -200° C.) the cleavage strength may be less than the yield stress and in such a case the crystal will break with a cleavage fracture without appreciable deformation.

Experiments on these lines are in progress in the Metallurgy Division of the Laboratory. Small tensile test pieces consisting of single crystals are made by a strain and anneal method, the final dimension over the test length being obtained by electrolytic machining which also leaves the surface of the crystal in a highly polished condition. The orientation of each crystal is determined by an X-ray method and the testpieces are broken in a Chevenard micro-testing tensile machine, the testpieces being cooled to a low temperature in specially designed Dewar flasks. It is of interest that results obtained to date indicate that over a wide range of orientation single crystals of iron are still completely ductile at -196° C., but a change to completely brittle behaviour may occur if the orientation is such that a (100) cleavage plane is inclined to the stress axis at angles not less than about 80°.

The Melting Point of Titanium

The determination of the melting point of titanium is difficult because of the metal's highly reactive nature. No refractory material is known which does not contaminate the molten metal, therefore conventional methods of determining its melting point cannot be used. Since it is difficult to conceive a method in which contact with refractories or other metals can entirely be avoided, a technique has been devised to reduce the possibility of contamination to a minimum while the melting point is determined under approximately black body conditions.

The specimen, consisting of a small cylinder about $\frac{3}{4}$ inch long and $\frac{1}{4}$ inch diameter, rests in a zirconia crucible provided with a lid with sighting hole. A recess in the base of the specimen ensures that only a small area of metal is in contact with the crucible. During an observation the filament of an optical pyrometer is focused on the base of a small axial hole drilled in the specimen. The specimen is slowly heated in a furnace consisting essentially of a tungsten spiral surrounded by radiation shields made of tantalum and molybdenum foil. The spiral, shields and electrodes are enclosed in a water cooled evacuated cylinder. When melting begins molten metal fills up the hole in the specimen and disturbs the black body conditions. The furnace is then shut down before the specimen collapses and reacts with the crucible.

The melting points of nickel and iron determined in the apparatus agree within 2° or 3° C., and that of platinum within 10° C. of the accepted melting points of these metals. The melting point observations obtained for titanium are reproducible to within 2° or 3° C. and a mean value 1,660 °C. is considered to be accurate within ± 10° C., which is the estimated accuracy of the pyrometer.

The Testing of Lifting Gear

Twenty years ago the great majority of lifting chains in use were made of wrought iron. This very ductile material is easily made into chain by hand forging and welding, and chain so made will usually extend by at least one-sixth of its own length before it breaks. This property of ductility is extremely important because under a sudden snatch, which cannot always be avoided in service, the chain will stretch and yet not break, while the stretch itself affords visible warning that the chain has been overloaded.

Wrought iron chains have to be periodically annealed because in service as a result of impacts of one link on another or on the ground the material is liable to become embrittled. When chain in this embrittled condition is subjected to a sudden jerk it is liable to fail without stretching, particularly in very cold weather. In recent years chains made of mild steel electrically welded in automatic machines have come into increasing use, and chains made of stronger steels are now becoming available. Some chains of this kind are immune from embrittlement, so that periodic heat treatment is not needed; but some are supplied for use in a heat treated condition.

All chain before it goes into service is subjected to a proof load twice the working load, and the chain must stand this without showing any signs of distress. In addition sample lengths from each batch of chain are tested to failure, and in this test also the chain has to meet very stringent requirements. A final check on the dangerous possibility of brittleness is afforded by actually breaking the chain by a sudden jerk. In the National Physical Laboratory tensile impact machine, the chain under test receives a sudden pull from a pendulum weighing about 2 tons. Only abnormally bad samples break without stretching and *most* stretch as much or more than they do under static loading; but not infrequently examination of a chain after the tensile impact test reveals slight imperfections of welding, which are not so apparent after static test. Manufacturers in developing new grades of chain are glad to avail themselves of this final test of the high quality of their product.

A High-Temperature Calorimeter

The steelmaker, in the cooling of large ingots, must know the thermal properties—conductivity and specific heat—of his steel, to obtain the best product; and there are many other high-temperature measurements on materials which are of importance to metallurgist, engineer and physicist. At the N.P.L. therefore a high-temperature calorimeter has been constructed, which is in essentials a large vacuum vessel, water-cooled on the outside, inside which an alumina pot can be heated by

radiant heaters up to a temperature of 1,600° C. (above the melting point of iron). Inside the pot, an alumina crucible holds the specimen (4 lb. of the purest iron, for example), and between crucible and pot an array of platinum radiation screens prevents heat exchanges as far as possible. Thermocouples measure the temperature difference between the pot and the crucible ; and an elaborate electro-pneumatic controller continuously adjusts the current to the heaters, to keep this difference equal to zero : i.e., the crucible neither gains nor loses heat from its surroundings. Further heat is supplied electrically to the crucible ; this all goes to heat its contents, and from a knowledge of the amount of this heat, and of the temperature rise produced, the specific heat of the contents may be calculated.

The apparatus is being used to measure the latent heat of melting of pure iron and of various steels, and the heats of transformation (from one crystal form to another) of iron and its alloys.

Standardisation of Radioactive Isotopes

Artificial radioactive isotopes are being used increasingly for medical and industrial purposes and, as in the case of the more common commodities, the user wishes to be assured that he is supplied with the amount of material he orders. Unlike most materials, however, artificial radioactive isotopes cannot be assayed by weighing because the amounts present are too small, and are inseparable from relatively large quantities of inactive material. Radiation detection devices such as Geiger-Muller counters and ionisation chambers can however detect the radiations emitted by the active material and, under certain conditions, can provide means of estimating the amount present. For certain applications in the fields of medical, biological and physical research, the highest possible accuracy is desirable and for this reason it is necessary to set up standard methods of measurement and standard specimens of radioactive isotopes. The National Physical Laboratory is collaborating with laboratories in this country, U.S.A. and Canada with the object of establishing national and international standards, particularly of specimens of the clinically important isotopes of sodium, phosphorus, cobalt, iodine and gold. The accuracy attainable is less than that traditionally thought of in connection with measurements in physics ; the work has shown so far that limits of $\pm 2\%$ are possible in favourable circumstances, with wider limits for the more complex isotopes.

Visit to Research Laboratories

Senior members of the teaching staffs of universities and technical colleges recently visited the Research Laboratories of British Insulated Callender's Cables, Ltd. at Wood Lane, Shepherd's Bush, and the Laboratories of British Telecommunications Research, Ltd. at Taplow Court, Bucks. The visit was arranged by the University Liaison Office which was established last year jointly by B.I.C.C., Automatic Telephone and Electric Co., Ltd. and B.T.R. to foster a closer relationship between the sponsor companies and the universities, technical colleges, public and grammar schools.

On arrival at Wood Lane, the visitors were welcomed by Dr. L. G. Brazier, Director of Research, B.I.C.C., who briefly outlined the functions of the laboratories. The tour included visits to the chemistry laboratories, where research is carried out into the chemistry of cable dielectrics, the physics laboratories where the electrical and physical characteristics of cable dielectrics are studied, and to the high-voltage laboratories which are equipped to carry out all the electrical tests required in research on cables, capacitors and overhead lines, for the highest transmission voltages.

After being entertained to lunch the visitors were taken to Taplow Court where they were received by Brigadier J. B. Hickman, Managing Director, B.T.R., who explained the activities of the Company. The laboratories visited included the radio laboratories which are devoted to the development of single and multi-channel radio systems in the V.H.F., S.H.F. and U.H.F. bands, and to the development of terminal and line equipment for coaxial cable systems. In the auxiliary research laboratories and the chemical and physical laboratories the visitors saw the production and testing of certain special materials, including ethylene diamine tartrate crystals and ferrites. Visits were also made to the electronic switching laboratories which are engaged on the application of cold cathode tubes and research into, and development of, magnetic drums for the storage of information, and their use in a register translator in a telephone exchange. The tour ended with a visit to the measurement laboratory which provides standards of measurements suitable for the work of the organisation, and undertakes maintenance of all laboratory test gear.

Before the guests dispersed there was an opportunity for questions which showed that the visitors had taken a lively interest in the tour.

New Cathode Ray Tube Factory

As a result of the ever-increasing application in industry of electronic devices and electronically controlled instruments, coupled with the very considerable increase in television, the Mullard Company has decided to establish a new factory for the manufacture of cathode ray tubes. The present manufacture of these tubes is mainly concentrated in the Company's factory at Mitcham, London, and following discussions with the Board of Trade it has been decided to transfer the manufacture to a new factory to be built under the facilities provided by the Distribution of Industry Act in the North-East Lancashire Development Area.

The factory will be one of the largest and most modern television tube factories, will provide employment for many hundreds of workpeople, and will make a valuable contribution to the diversification of industry in the textile towns of North-East Lancashire. The transfer of the work from Mitcham will make much needed space available for the manufacture of other electronic devices and this will absorb the workpeople at present employed on television tubes there. The new factory will be within easy reach of the Company's existing factory at Blackburn, which will be responsible for providing certain materials and component parts and services to the new factory. It is confidently expected that the provision of these services together with increasing demand for existing and new products of the Blackburn factory will require an expansion of that factory's labour force.

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